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The Journal of the American Welding Society

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Structural and Metallurgical Properties of Condenser Discharge Spot Welds*

By G. S. Mikhalapov† and T. F. Falls‡

THE development of condenser discharge type of spot welding has been prompted largely by the welding requirements of light alloys, principally aluminum and magnesium alloys as used in the aircraft industry. Since then this type of equipment has been used on other metals with good results but it still remains primarily a method of welding aluminum so that any discussion of condenser discharge spot welds is bound to evolve to a large extent on aluminum spot welds.

Accordingly this discussion will be confined primarily to the properties of spot welds made on aluminum alloys of the type used in aircraft industry and generally referred to by their trade numbers 24ST, 24ST Alclad, 52S and to some extent 3S half and full hard.

The metallurgical properties of aluminum spot welds have been frequently discussed to the point where almost everyone interested in resistance welding has at some time or another seen various microphotographs showing the metallurgical structure throughout the weld metal and adjoining parent metal of spot welds made on aluminum alloys. Thus it is well known that the weld metal of any aluminum spot welds shows the unmistakable characteristics of the large grain casting while the parent metal adjacent to the weld which is usually a wrought metal exhibits varying degrees of intergranular fusion depending on the type of weld and upon the distance from the center of the weld. In the spot welds made with ordinary alternating current, the central cast structure consists of layers of cast metals produced by the progressive melting and cooling of the parent metal occurring in each successive cycle of the weld producing current. In the condenser discharge or in fact in any stored energy weld where this directional impulse of current forms the weld these layers of cast metal forming the nugget are absent and the true structure of the weld, unobscured by these alternating meltings and freezings, can be studied.

The average stored energy spot weld when sectioned at right angles to the plane of joint and then suitably polished and etched shows a central zone or nugget of coarse cast metal which has apparently cooled at a fairly slow rate since the grain structure is usually coaxial. This central zone or nugget is surrounded by a skin or layer of cast metal which shows evidence of cooling at a very high rate and perhaps to some extent of cold work though on this last point considerable disagreement still exists. The grain structure of this outer zone is definitely dendritic or columnar in structure.

Fig. 1—Showing Characteristic Structure of Central or Co-Axial Zone. Weld in 24ST Alclad. 500 X Keller's Etch

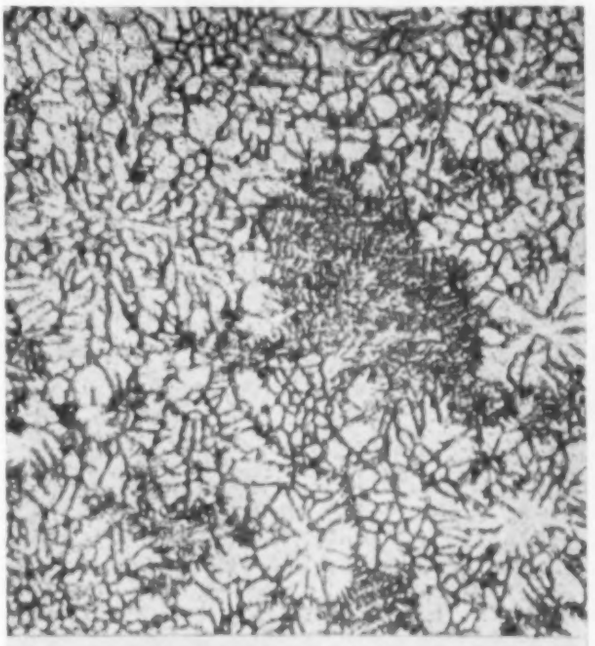

Fig. 2—Showing Characteristic Columnar Structure of Weld in 24ST Alclad. 500 X Keller's Etch

* Presented at the Annual Meeting, AMERICAN WELDING SOCIETY, Philadelphia, Oct. 20 to 24, 1941.
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Fig. 3—Wide Heat-Affected Zone. Weld in 24ST Alclad. 500 X Keller's Etch

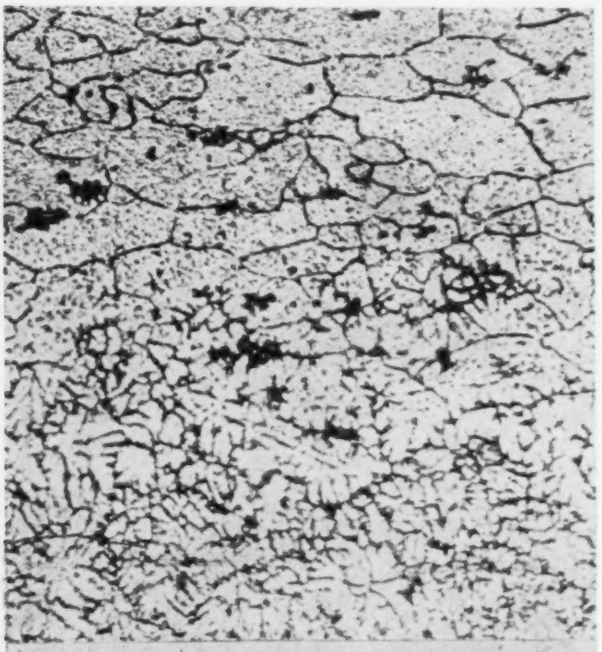

Fig. 4—Very Narrow Heat-Affected Zone. Weld in 24ST Alclad. 500 X Keller's Etch

It has been long argued that the outer or columnar layer of the weld is stronger or at least tougher than the central coaxial nugget. This is probably true though to date no definite evidence to this effect has been produced.

Figures 1 and 2 show the central and the columnar zones of section made through the weld.

Surrounding the weld nugget is a zone of parent metal which has been appreciably affected by the heat of the weld. This heat-affected zone consists primarily of the original wrought metal grains surrounded by metal which has reached liquid or semi-liquid state. Apparently what happens is that the impurities and alloying elements lying along the grain boundaries have melted first while the grains themselves are still in their original conditions.

This evidence of granular fusion is most pronounced around the periphery or the edge of the weld, i.e., in that part of the parent metal which is nearest to the weld yet farthest from the cooling mass of the weld electrode. That this is so is of course very natural since the rate of cooling would be slowest in this region. The extent or thickness of the heat-affected zone around the weld nugget varies both with the rate at which the weld is made and with the thickness of the weld casting, commonly known as the weld penetration On welds made at a comparatively slow rate and with weld penetration of 50 or 60% of the metal thickness, the heat-affected zone, particularly at the periphery of the weld, frequently may extend to, or nearly to, the surface of the metal. The strength characteristics of the heat-affected zone is again not definitely known though it is generally conceded and often argued that it is weaker than the original structure and certainly less ductile.

Figures 3 and 4 show the extent to which the heat-affected zone can extend around and beyond the weld.

These then are briefly the three major metallurgical characteristics of aluminum spot welds. They are well known as originally stated and little can be gained by discussion as to their significance.

In addition to the three main or normal states of a weld the microscopic examination frequently reveals a number of irregularities within these states which are sometimes described as flaws or defects. The most common of these are, of course, tiny gas cavities or blowholes formed by gas formation or actual physical expulsion of the metal from a weld and small cracks or fissures occurring upon solidification of the molten nugget. These can frequently be seen with a naked eye and are, strictly speaking, mechanical defects in the weld structure and as such will be discussed later on. In addition to these more common defects the weld structure frequently exhibits other abnormalities such as inclusions of small particles of oxides or other impurities picked up from outside of the sheet or of the alloying elements, or even of the protective coating or clading if such is used on the metal welded.

Figures 5, 6, 7A, 7B show marked cases of each of these defects.

Fig. 5—Typical Cavities Occurring in Weld in 24ST Alclad. 10 X Keller's Etch

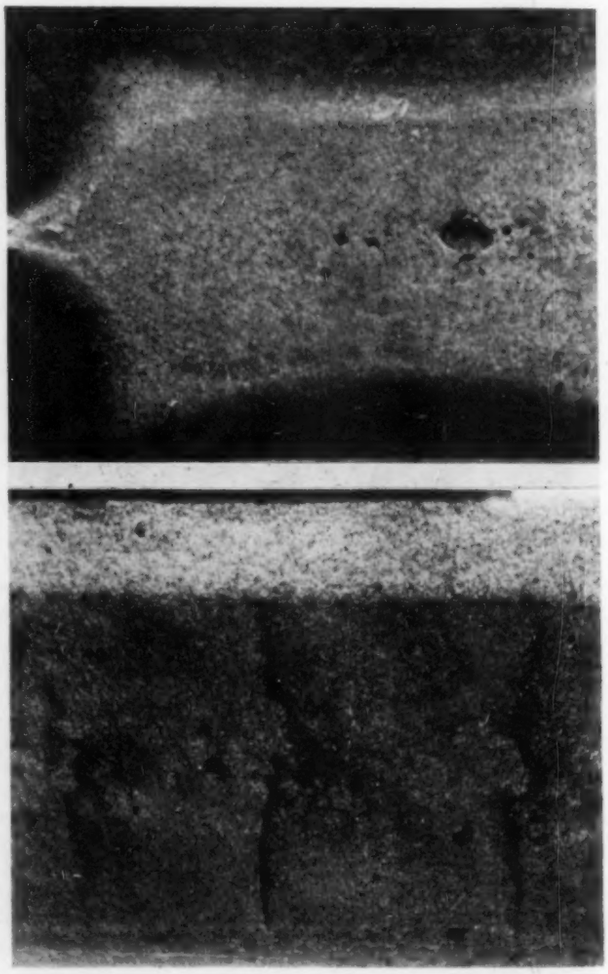

Fig. 6—Severe Case of Cracks Occurring in Weld in 24ST Alclad. 5 X Keller's Etch

The structural significance of inclusions is again not very clear. It is generally supposed and some of the recent fatigue investigations have substantiated this view that these inclusions form focal points of weakness since they interrupt the homogeneity of the weld structure and act as local stress raisers, however it is still problematic that this reduction of fatigue strength is of any great magnitude. The fatigue failures, when they occur in a mechanically sound spot weld, always originate at the inclusion if and when it is present. That they originate at a value substantially lower than that of failures occurring in spot welds sound in all respects and where failure usually starts at the point of normal stress concentration such as the edge of the weld, has not been definitely proven.

A somewhat discouraging aspect of the metallurgical examination of the weld is that it does not contribute very much to our ability to foretell the structural properties or the structural behavior of the spot weld in service, but rather helps us to understand better the reasons of the structural phenomena, once these have been found out by other means. In general all aluminum spot welds made with a single impulse of direct current in a reasonably short time exhibit the same metallurgical traits, at least as evidenced by the metallographic examination. It is true that the ratio of the volume of the central coaxial structure to the surrounding columnar shell vary in different welds. It is also true that statements and claims have been frequently made that the welds possessing the thickest columnar shell as compared to the central coaxial nugget are stronger or tougher or more ductile. However, when viewed in a light of cold scientific analysis, these still remain at this date nothing but theories—plausible and logical, it is true, but still unsupported by any factual proof.

The significance of the heat-affected zone around the weld appears to be somewhat clearer than that of its internal structure. The metallurgical examination of this heat-affected zone tells us that it should be first, lower in strength than the parent metal, and, second that it should possess less ductility. We can accordingly expect that whenever failure occurs around the weld and therefore through the heat-affected zone it should do so at a unit stress considerably lower than that of the parent metal. This is actually the case, as will be seen later. Because of the reduced ductility it can also be expected that any load, of the type which would require an appreciable strain either elastic or plastic to take place in the metal around the spot weld, in order that the spot weld may carry it, applied to an aluminum spot weld causes failure at a much lower value than in cases of welds made on materials which have a soft ductile zone around the weld. This also is found to be true and can be easily demonstrated by the direct tension or U-type specimen tests.

In the direct tension test the method of applying the load to the spot weld is such that unless the metal around the weld can bend and plastically deform to the point where it finally fails in straight tension, the moment at the periphery of the weld will cause the metal at the periphery to fracture in bending at a comparatively low load. For instance, in spot welds made on such air hardening materials as 11% chromium steel, high carbon steels or chrome-molybdenum steels where the ductility of the zone around the welds is extremely low, the brittle fractures will take place around the weld with a very low load applied to the sheet at the standard distance of 1 or 2 inches, without any deformation of any kind of the specimen taking place. The aluminum alloy spot welds also exhibit in general a comparative low ratio of tension to shear strength which confirms the conclusion of the poor ductility of the heat-affected zone.

Fig. 7(*a*)—0.032-In. Stock 50 X

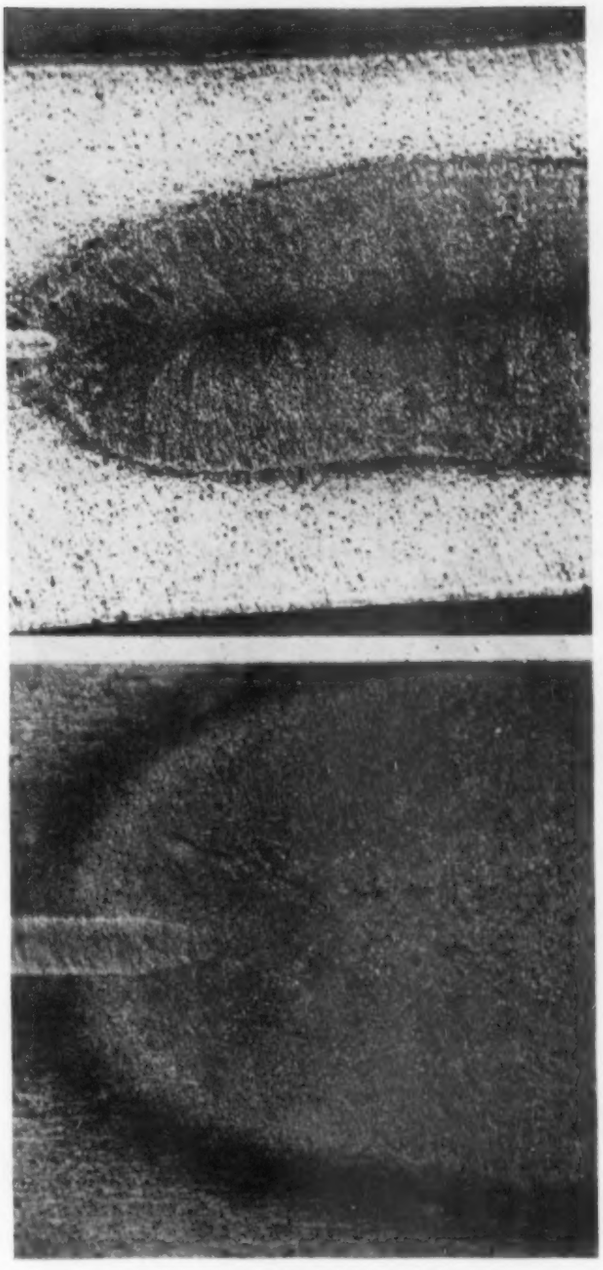

Fig. 7(*b*)—0.064-In. Stock 50 X

Figs. 7(*a*) and 7(*b*)—Characteristic Defects Due to Inclusions. 24ST Alclad Welds. Keller's Etch

Before discussing the structural properties of aluminum spot welds as such it may be well to review in general some of the fundamental laws governing the strength of any structural, point type joint between two surfaces whether it be spot weld, plug weld or a rivet.

The strength of any spot bond is the function of the dimensions and unit strength of the bonding body and of the dimensions and unit strength of the parts joined at the point of the bond. In case of a spot weld the strength of the bond is a function of the spot weld diameter, its unit strength and of the thickness and unit strength of the sheets joined.

The approximate strength of any spot weld in these

terms is then given by the following formulas, when the spot is stressed in ordinary lap shear:

$$(1)\quad \frac{d^2\pi\, T_w}{4} \quad \text{and}$$

$$(2)\quad d\,\pi\, t\, T_p k$$

where

d = Diameter of spot weld.
T_w = Tensile strength of weld metal in shear.
t = Thickness of the thinnest stressed sheet in the joint.
T_p = Tensile strength of the parent metal in tension.
k = Constant expressing the annealing or air-hardening effect of the heat of the weld on the parent metal immediately adjacent to the weld.

Formula (1) holds until the parent metal around the weld fractures.

Formula (2) applies after the parent metal around the weld fractures.

The critical diameter at which the parent metal fractures is then given by the formula:

$$(3)\quad d_c = \frac{4\, t\, k\, T_p}{T_w}$$

These formulas have been used to a large extent in determining the structural properties of welds made on steels and in general have proved to hold very closely. Figure 8 shows a family of curves plotted in accordance with them.

The parabolic parent curve represents the strength of any weld failing through shear in the plane of joint. It is therefore obtained by multiplying the area of the weld in the plane of joint by the shear strength of the weld metal. In actual practice this parent curve would be a family of curves, depending on the value of the shear strength of the weld metal which will vary to some extent for different metals. This variation is much less than could be at first expected and an average value of 65,000 psi. gives a close approximation to the actual values exhibited by almost all steels.

The family of straight lines departing from the parent curve represent failures around the periphery of the weld through the parent metal adjacent to the weld. As could be expected and as can be seen from an examination of Figure 8 they are a function of the thickness of the sheets joined and of the tensile strength of the parent metal immediately adjacent to the weld. For most steels the factor k which gives the relationship between the heat-affected zone and the parent metal does not vary more than $\pm 10\%$ of unity, the most common value applying to all mild carbon steels being around 0.95.

It has been generally conceded in the past that in order to possess a safe structural strength a spot weld should be large enough to fail around its periphery through the parent metal rather than through its plane of joint. There are a number of reasons for this rule, the principal one being the greatly increased ductility of the joint which can stand considerable distortion and deformation without failure. It is particularly appreciable in case of alloys exhibiting definite brittleness around the periphery of the weld where it has been customary to increase the

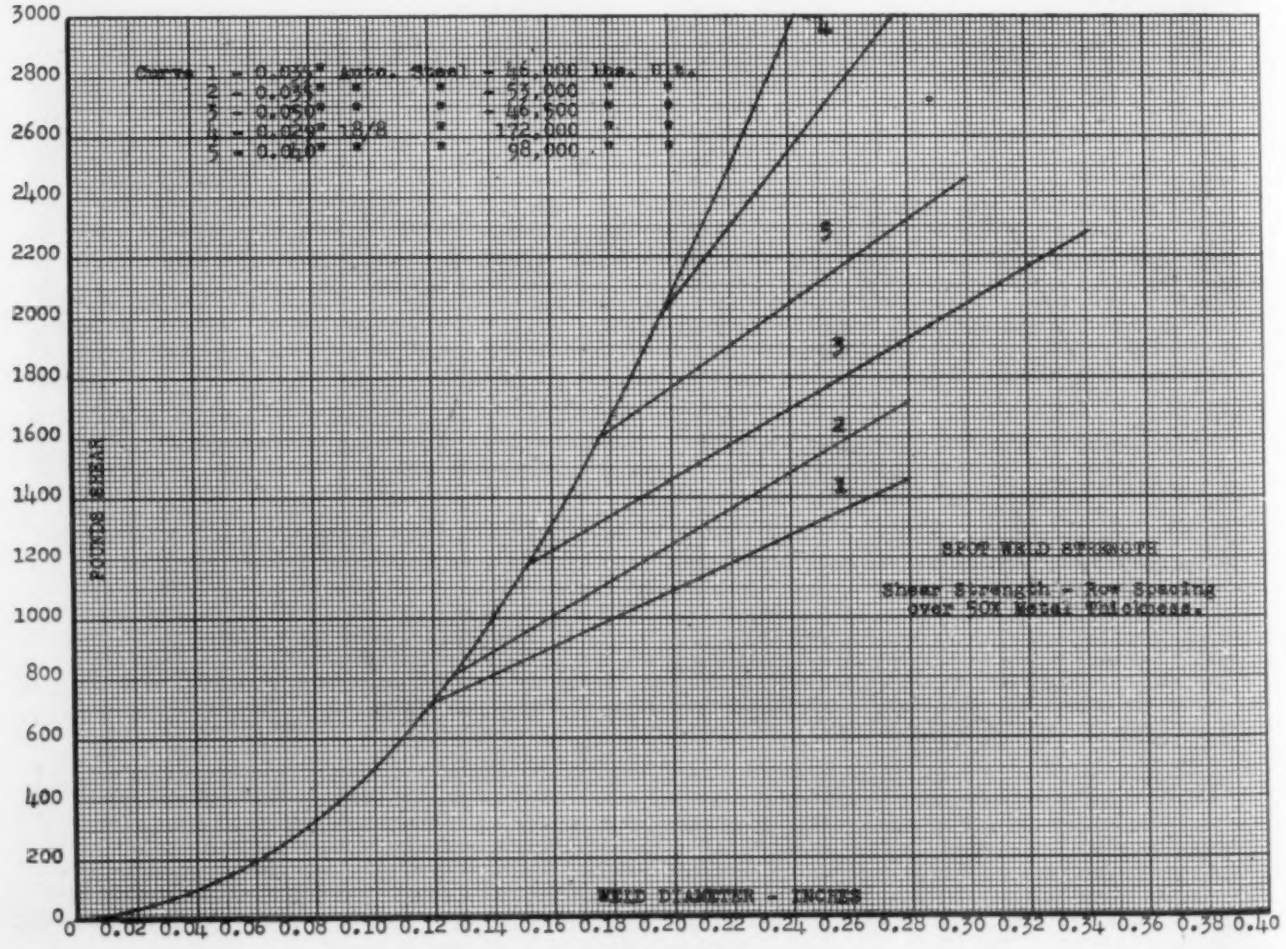

Fig. 8

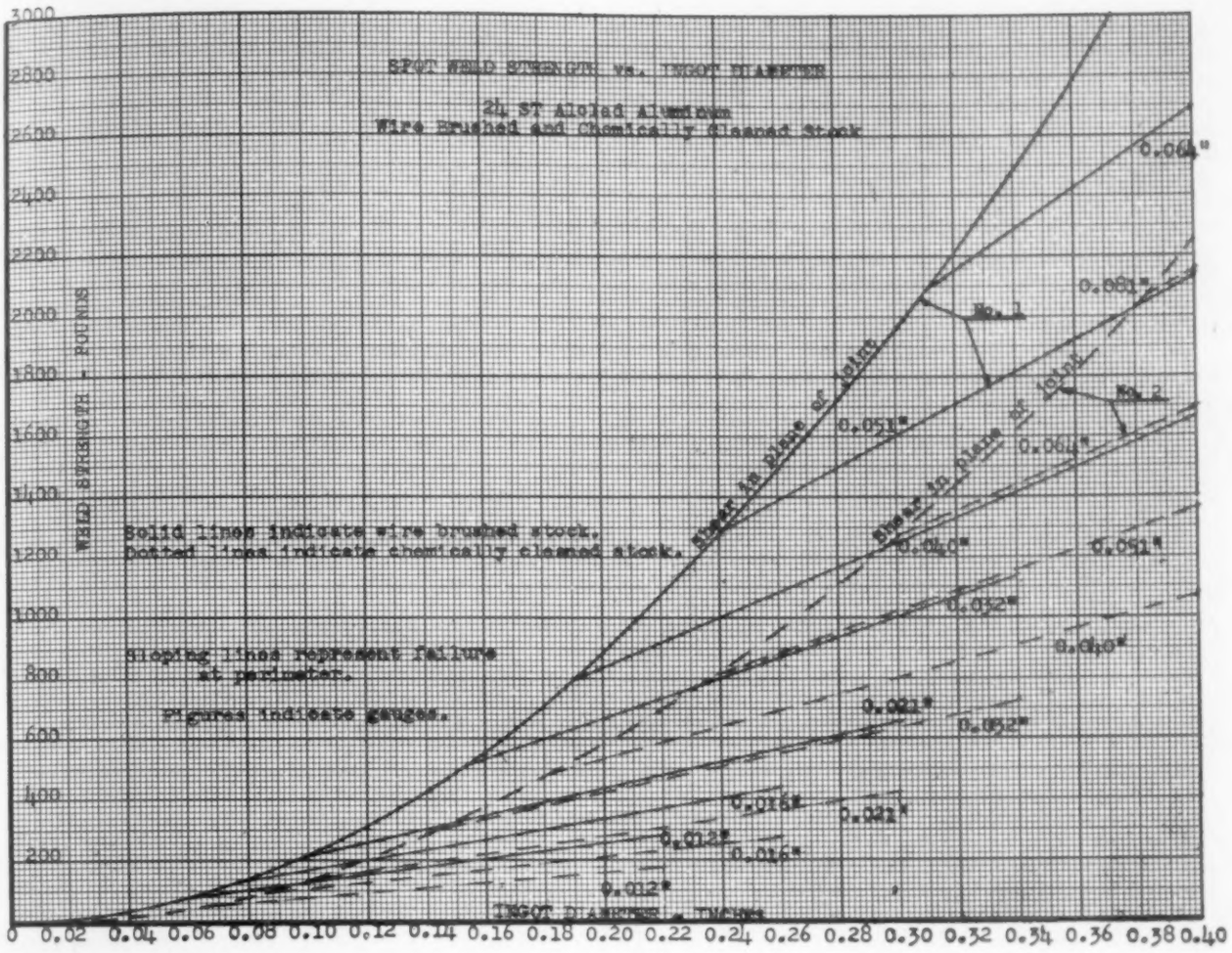
SPOT WELD STRENGTH vs. INGOT DIAMETER
24 ST Alclad Aluminum
Wire Brushed and Chemically Cleaned Stock
WELD STRENGTH - POUNDS
INGOT DIAMETER - inches
Solid lines indicate wire brushed stock.
Dotted lines indicate chemically cleaned stock.
Sloping lines represent failure at perimeter.
Figures indicate gauges.
No. 1
No. 2
0.064"
0.081"
0.051"
0.040"
0.032"
0.025"
0.021"
0.016"
0.012"
0 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22 0.24 0.26 0.28 0.30 0.32 0.34 0.36 0.38 0.40
200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000

Fig. 9

diameter of the weld well beyond the junction point of the tear failure to the shear failure curves. Since a spot weld is fundamentally a form of a joint its method of failure in relation to its size is primarily the same for all types of metals and therefore we should expect aluminum spot welds to follow in general the rules applying to the steel spot welds. With some interesting minor exceptions this appears to be borne out by the results of an investigation of the relationship of spot weld diameter and its shear strength, summarized on Fig. 9. Figure 9 shows a family of curves identical to those shown in Fig. 8 except that the material is 24ST Alclad aluminum alloy. It will be noted that the same parabolic curve representing failure in shear through the plane of joint and the same type of family of straight lines issuing from the parent curve and representing periphery or parent metal failure are present. The unit values however are entirely different. While the yield and ultimate strengths of 24ST Alclad aluminum are between those of mild carbon and annealed 18–8 stainless steels, namely 41,000 and 62,000 psi. respectively, the apparent average unit shear strength of the weld metal referred to area of the ingot as shown on the heavy line curve is only 27,500 psi. Furthermore, the average strength of the parent metal adjoining the weld, instead of being within 90% of that of the parent metal as is true in case of steels is now only a little better than 33,000 psi. or 50% of the strength of the parent metal. The picture is further complicated by the fact that the 27,500 psi. value is only true for a certain type of surface preparation wherein a corona of bonded Alclad material is formed around the weld during the weld process. The unit strength of the pure aluminum corona weld is in the neighborhood of 9500 psi. but since it extends around the weld its total area frequently approaches that of the alloy ingot area itself and wherever it is present it contributes considerably to the total strength of the spot weld. The average unit shear strength of the alloy weld is only 18,000 psi.

This radical change in the behavior of the 24ST aluminum alloy spot welds from that of steel spot welds is not surprising when we remember the fact that the principal strength of 24ST alloy is derived from heat treatment. The central cast zone of the weld is probably 24SO metal since this alloy has the same shear strength of 18,000 psi. This value is closely checked by the value obtained in our investigation.

The value of 27,500 psi. used for the first curve is fundamentally a synthetic one as it represents the strength of the ingot at 18,000 psi. plus the strength of corona area at 9500 psi. divided by the area of the ingot only. However, as it is much easier to measure the area of the ingot alone rather than that of the ingot and the corona this composite average value of 27,500 psi. was used, while a separate curve, No. 2, shown in dotted lines was plotted to represent the strength of welds possessing no bonded corona. Since the difference between 27,500 and 18,000 figures is over 33% it becomes much more difficult to predict at what point the shear failure will cease and a tear failure will begin. With surface preparations resulting in practically negligible contact

resistance and with the use of higher pressure the corona effect is very pronounced and the No. 1 curve can be used with a fair degree of accuracy. With some types of chemically cleaned surfaces where the contact resistance is apparently high and also with low pressure welds there appears to be a complete absence of bonding in the corona and the dotted line curve applies. Between these two values, however, there appears to exist a number of intermediate conditions of pressure and surface preparation where a much smaller or incompletely fused corona is present. The effective unit strength then is between 27,500 and 18,000 and the weld strength follows a curve intermediate between 1 and 2.

When chemically cleaned buttons are of sufficient diameter to tear around the weld, it is expected that the strength will be above 18,000 psi. since not all of the surface along which failure occurs is in the heat-affected zone. On the other hand, lower values than in the case of wire brush preparation will develop since there is no bonding in the corona to contribute strength. Unfortunately, there were available, scarcely sufficient samples of this type of failure with chemical cleaning to establish a value with certainty. Six samples were studied with resultant stress values lying between 19,800 and 22,200 psi., and an average of 21,300. This last value was used in preparing curve No. 2.

It will be noted that the unit values mentioned so far are average values. While the unit strength of steel spot weld metal is in general fairly consistent for steels of the same analysis, the unit shear strength of the 24ST aluminum alloy varies considerably.

The temptation immediately arises to conclude that different welding techniques produce welding metal of different unit strengths. Indeed this contention has been voiced before and at first appears to be very logical since the metallographic examination frequently reveals a difference in spot weld structure made with different techniques. However, a close examination of the data obtained during the investigation does not bear out this contention. Since the welding conditions and the cooling cycle are entirely different for thin gage materials than for heavy gage materials, it would be logical to suppose that the unit strengths shown by welds made on these different gages would exhibit a marked difference. Indeed the metallurgical structure of welds made on 0.020-inch material is considerably different from those made on 0.081-inch material since in general the thinner gage with its much more rapid cooling cycle exhibits structure where the outer dendritic shell constitutes by far the largest proportion of the weld. In the 0.081-inch material on the other hand, where the cooling cycle is much slower, the central or the coaxial state is far larger in volume than the outer dendritic shell.

Figures 10A, 10B, and 11 show the marked difference in proportion between the central zone and the dendritic shell that may exist in perfectly sound weld in various gages of material.

In examining Table 1 which gives the summary of the test results obtained on wire brushed materials, we note that the ingot unit strength for 0.020-inch material appears to be in the neighborhood of 18,700 psi. while that for 0.081 inch only 16,600 psi., or a variation of $\pm 6\%$ from the average. This at first appears to bear out the fact revealed by metallographic examination. However, on further examination we note that 0.038-inch material shows the unit strength of only 15,800 psi. while both 0.032-inch and 0.051-inch material exhibited the same strength of 17,500 psi. The net evidence is, therefore, inconclusive.

However, a still greater upsetting factor is revealed when we examine the minimum and maximum limits of the unit strength of welds made on the same gage thickness with identical welding conditions. These range from 14,000 to 23,000 psi. in case of 0.020-inch material or a difference of approximately $\pm 25\%$ from the average to a variation of 14,400 to 19,400 psi. or a variation of -13%, $+17\%$ for 0.081-inch material. Even allowing for a considerable margin of error in measuring the weld area as well as the actual total strength of each spot weld the difference in unit strength of supposedly identical welds is still sufficiently great to nullify any conclusion which may be drawn from the first examination of the unit strengths of various gage combinations.

Examining the summary of results obtained on the welds failing around the periphery of the weld, an equal variation in unit strength exists. Thus, the unit strengths of individual spot welds made under exactly identical conditions on 0.020-inch material vary from 26,700 to 36,900 or -17%, $+13\%$ from the average while those made on 0.032-inch material vary from 31,100 to 40,000, or -11%, $+15\%$ from the average.

It would appear therefore that the only justifiable conclusion to be made is that appreciable variation exists in the unit strengths of weld material which cannot be attributed to either the difference in the welding condition nor is revealed by metallographic inspection.

It is possible that with more exact means of spot weld diameter measurements the apparent spread in the unit values will be narrowed. It does not appear probable, however, that it will be completely eliminated as even allowing for a possible present error of $\pm 5\%$ a variation of as much as $\pm 15\%$ will still exist in some cases.

There is still one more aspect of the structural properties of spot welds which may have some effect on the apparent variation of the unit strengths, namely the mechanical defects in the weld such as cracks and porosity. However, this has to be discarded as none of the welds tested showed any such defects in either the tested specimens or in the welds sectioned and examined metallographically and made under the identical welding conditions. Furthermore, it has been a universal experience of everyone testing spot welds that the physical defects inside the weld nugget do not affect the shear strength of the weld as measured by the standard lap shear test.

Fig. 10(*a*)—0.021-In. 24ST Alclad 10 X Keller's Solution

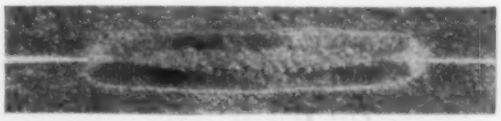

Fig. 10(*b*)—0.032-In. 24ST Alclad 10 X Keller's Solution. Showing Welds with Large Dendritic Shell and Relatively Small Central Zone

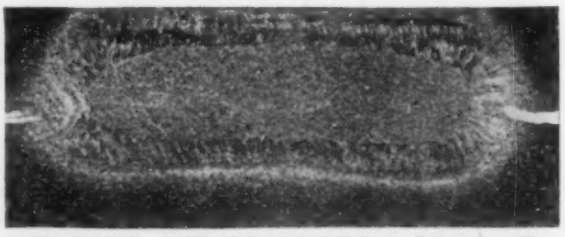

Fig. 11—0.064-In. 24ST Alclad 10 X Keller's Solution. Showing Weld with Large Central Zone and Proportionately Small Dendritic Shell

Table 1—Summary—Weld Strength Data

Metal Thickness	Method of Cleaning	Manner of Failure	No. of Spots	Weld Diam. 1. Average 2. Maximum 3. Minimum	Apparent Psi. of Weld Ingot or of Weld Peri. 1. Average Value 2. Maximum Value 3. Minimum Value	Psi. of Weld Ingot Only 1. Average Value 2. Maximum Value 3. Minimum Value	Psi. of Corona of Fused Alcladding 1. Average Value 2. Maximum Value 3. Minimum Value
0.020	Wire Brushed	Shear Through Ingot	15	1. 0.108 2. 0.115 3. 0.095	1. 28,600 2. 38,600 3. 22,500	1. 18,700 2. 23,600 3. 14,000	9500-psi. Assumed for Calculations
0.032	Wire Brushed	Shear Through Ingot	4	1. 0.186 2. 0.190 3. 0.180	1. 23,600 2. 25,000 3. 21,800	1. 17,600 2. 19,300 3. 16,100	9500-psi. Assumed for Calculations
0.038	Wire Brushed	Shear Through Ingot	16	1. 0.182 2. 0.190 3. 0.175	1. 24,100 2. 26,000 3. 19,600	1. 15,800 2. 18,700 3. 11,800	9500-psi. Assumed for Calculations
0.051	Wire Brushed	Shear Through Ingot	16	1. 0.192 2. 0.210 3. 0.175	1. 30,400 2. 38,500 3. 25,000	1. 17,600 2. 21,800 3. 11,400	9500-psi. Assumed for Calculations
0.064	Wire Brushed	Shear Through Ingot	16	1. 0.236 2. 0.250 3. 0.225	1. 27,300 2. 30,800 3. 23,600	1. 16,900 2. 20,000 3. 13,400	9500-psi. Assumed for Calculations
0.081	Wire Brushed	Shear Through Ingot	16	1. 0.283 2. 0.310 3. 0.240	1. 27,600 2. 35,600 3. 22,400	1. 17,200 2. 20,000 3. 15,200	9500-psi. Assumed for Calculations
0.020	Wire Brushed	Failure Around Weld Periphery	16	1. 0.147 2. 0.160 3. 0.135	1. 32,000 2. 36,900 3. 26,700	1. 17,500 2. 19,900 3. 12,100	9500-psi. Assumed for Calculations
0.032	Wire Brushed	Failure Around Weld Periphery	16	1. 0.180 2. 0.185 3. 0.170	1. 34,800 2. 40,000 3. 31,100	1. 25,100 2. 30,000 3. 21,000	9500-psi. Assumed for Calculations
0.040	60 sec. in 6% HF	Shear Through Ingot	15	1. 0.197 2. 0.210 3. 0.180	1. 16,600 2. 21,800 3. 10,800	....	.....
0.040	12 min. at 170° F. in Oakite 31W 12 oz./gal.	Shear Through Ingot	17	1. 0.173 2. 0.180 3. 0.160	1. 21,500 2. 24,000 3. 18,200	....	.....
0.040	60 sec. in 6% HF. Steel Wool	Failure Around Weld Periphery	6	1. 0.183 2. 0.190 3. 0.180	1. 21,300 2. 22,200 3. 19,820	....	.....
0.040	Wire Brushed	Shear Through Corona	16	1. 0.241 2. 0.250 3. 0.225	....	....	1. 10,390 2. 12,200 3. 8,680
0.040	Wire Brushed	Shear Through Corona	13	1. 0.245 2. 0.250 3. 0.240	....	....	1. 10,810 2. 12,230 3. 9,200
0.040	Wire Brushed	Shear Through Corona	5	1. 0.254 2. 0.260 3. 0.250	....	....	1. 10,690 2. 12,230 3. 9,440
0.081	Wire Brushed	Shear Through Corona	3	1. 0.380 2. 0.380 3. 0.380	....	....	1. 8,910 2. 9,550 3 8,320

Insofar as the effect of those defects is concerned on the possible fatigue performance of spot welds, such investigations as have been conducted recently, appear to justify the same conclusions as the one made in case of weld inclusions, namely that although fatigue failures always begin at the point of the defect such as a crack or a cavity, whenever these are present, the failure of spots not exhibiting these defects does not appear to occur at appreciably lower value than those exhibiting such defects. At the present time, however, the available data is incomplete so that this statement cannot be taken as definitely correct and must be simply considered as a temporary conclusion which such results as now are available appear to indicate.

The numerical data of the investigation on the basis of which the above conclusions were made embraces a total of over 200 spot welds made on 0.020, 0.032, 0.038, 0.051, 0.064, and 0.081-inch materials. Three types of cleaning, namely wire brushing, hydrofluoric acid etch, and Oakite 31W etch were used. Welds of different types were obtained ranging from corona welds only, i.e., wherein the fusion was confined to alclad coating only to welds wherein corona was completely absent and the entire strength of the weld derived from the alloy nugget. Condenser discharge equipment of standard make was used and the welding conditions were such as to produce welds of required diameters without internal defects or inclusions. Oscillographic records of the current and pressures used were made at frequent intervals to ensure that identical welding conditions were maintained.

Engineering Essentials for Welders*

H. Malcolm Priest†

Foreword

IN this paper the author has undertaken a presentation and discussion of the engineering aspects of welding residing in the hands of the welders and those immediately responsible for fabrication and erection of welded structures, with the object (1) of establishing a more-or-less common ground of understanding, between designer and builder, of the principles of engineering involved in the welding of a structure if it is to perform its expected function efficiently and safely and (2) to emphasize the necessity, on the part of the welder, of carrying out his portion of this important partnership. In attempting to cover so wide a field within the limits of a single paper, it has seemed best to present the general outline first, leaving until later the more extensive discussion of important phases of welding.

Introduction

Any completed structure represents the combined work of the hands and minds of many persons. A brief enumeration would include the owner, architect, engineer, contractor and the skilled workmen who carried out the actual construction from the plans and drawings. Out of this group let us take the engineer and welder for consideration, because they stand in a particularly close relationship. Upon them rests the joint responsibility for the safety of a welded structure and of those who enter the building or ride over the bridge.

The primary responsibility falls upon the engineer, since the best of welding cannot prevent the failure of an inadequate design but, on the other hand, poor welding can undo the best of designs. Only about fifteen years have elapsed since welding began to crowd itself upon the attention of structural engineers. Quite naturally, there were hesitation and questioning upon their part as to the safety of this new process of fabrication. It is a credit to the engineering profession and the welding industry that no major failure of a welded structure has occurred in this country during this period, when welding has been establishing itself as an accepted and common method of fabrication. But this record was not achieved without careful study and investigation of all phases of the problem.

What were some of the questions raised by engineers in those early days? Among them were these:

1. Strength of welds.
2. Variations in strength from high to low values.
3. Relation of a welder's qualification test to his subsequent performance.
4. Merits of different types of joints.
5. Costs of welding.

The Structural Steel Welding Committee of the American Bureau of Welding was organized in the fall of 1926 to obtain reliable information upon the strength of welds and to determine what degree of uniformity in commercial welding might be expected. The work of that committee covered a period of five years and the results of its investigation did much to assure engineers and builders as to the safety of welded construction.

The success of any project depends upon careful attention to details. It was important to learn what factors contributed to the success of welding. First-hand observations were made of welders at work to discover facts relating to comparative ease or difficulty of making welds in flat, vertical and overhead positions and a host of other items such as the amount of welding deposited in a given time, sizes of electrodes, current and voltage to be used and means for simplifying shop operations. Out of such observations and experiences have grown those present-day practices which are the basis for the expanding use of welding in industry.

It has been pointed out that safety of the structure is the responsibility of the engineer and welder. The safety of lives is properly the concern of public officials and we find various codes and regulations governing the design and construction of buildings, bridges and various other structures. The fitness of an engineer to design a structure is often determined from his past record and experience and in many states he is required to be licensed. In such cases, a Board of Examiners investigate his record and may require him to take written examinations. When satisfied that he is competent to design structures, the Board grants him a license to practice and requires him to put his seal on all drawings and reports as evidence of his responsibility.

Similarly, a welder is required to satisfy public authorities as to his ability and skill in making acceptable welds. The means for accomplishing this purpose is the so-called qualification test. Along with his past experience, this test is expected to, and does provide good evidence of a welder's competence. Such a test has to be related closely to the type of welding to be done. The writer recalls that the welders who applied for structural work in the early days had, naturally, no experience with heavy material but were trained in welding light-gage material such as automobile bodies. They could not make the test plates stick together at first and a period of practice was required. Like the engineer, the welder has to demonstrate his fitness, and the stamp of public approval is a valuable asset and a matter for pride of workmanship.

The mutual interests of engineer and welder make it desirable that they understand each other's work. From necessity, the engineer has to concern himself with matters of fabrication. The welder can benefit from a knowledge of the engineer's role in construction and can derive satisfaction from an appreciation of what lies behind a design and how it is developed. The writer has been asked to present the engineering side of the welding of steel structures and it will be his endeavor to do so from a practical, rather than a technical viewpoint.

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Forces and Stresses

The science of engineering deals with forces and the stresses which they produce. Only by a clear understanding of the terms in which engineers think and speak can we intelligently approach engineering design. It is proper, therefore, that some of the common terms should be defined and discussed to an extent that will make their meanings unmistakable. Technical men and scientists strive for exactness and precision in their language, because the more precise their use of words, the less chance there can be of conveying an uncertain meaning. We are not so exacting in our everyday conversation and writing.

For a definition of *force* we go back to the subject of physics. Force is a name that is given to that influence of one body on another by which the first changes, or tends to change, the motion of the second. At first, that definition may sound rather difficult, but an illustration will clarify it. Let us imagine a weight hanging motionless on a string. If we push sideways on that weight with our hand, the weight will immediately move in the direction of the push. The influence (push) of our hand upon the weight is the force. Had the weight been touching a wall on the opposite side from the push, no perceptible motion would have occurred, although the tendency to move would still have been present and, as in the first instance, we would have exerted a force. Most structural engineering problems deal with conditions under which motion only tends to take place. When a train goes over a bridge it exerts a whole series of forces on the bridge but, neglecting small deflections, the structure is prevented from moving bodily by the abutments or piers which resist the forces.

If two men have hold of opposite ends of a rope and one man pulls on the rope, the other will immediately feel that pull. Evidently, the force of that pull was transmitted through the rope and this internal force is called tension. Likewise, if the two men are holding the ends of some member that is capable of transmitting a push, the internal force produced by a push is called compression. Forces, external and internal, are usually measured in pounds. When reduced to its simplest terms, the designing engineer's function is to select a size of member that will not fail under the action of these internal forces. In practice, it is far from as simple as that.

The term "intensity" of the internal force can perhaps be most easily understood from an example. Suppose we have an internal force of 400 pounds in a bar 2 x 2 in. cross section. The cross-sectional area of the bar is 4 sq. in. If we divide the force (in pounds) by the area of the bar (in square inches) we have $\frac{400}{4} = 100$ lb. per sq. in. (psi.), which is called the intensity of the internal force.

When we come to the definition of *stress* we have to face the somewhat confusing fact that the word is used with two meanings. In spite of a desire for exactness, this dual meaning is so deeply rooted in engineering practice that it has to be recognized. Many times the intended meaning of the word will be clear from its context, but where any doubt may arise one is immediately placed under the necessity of adding such qualifying words as will make the meaning clear.

From long and well-established practice, engineers have come to speak of stress as the internal force in a member, and of unit stress as the intensity of that internal force. Many text-books, handbooks and specifications use the terms stress and unit stress in these senses. For reasons of exactness and convenience of expression, recent writers on the subject of the fundamental principles of stress have used the word stress to mean intensity of internal force. Likewise, the American Society for Testing Materials has adopted the same meaning in its standards. (See A.S.T.M. Designation E6–36.) Even engineers, at times, use the word stress in both senses. We have, then, the following situation with respect to this term:

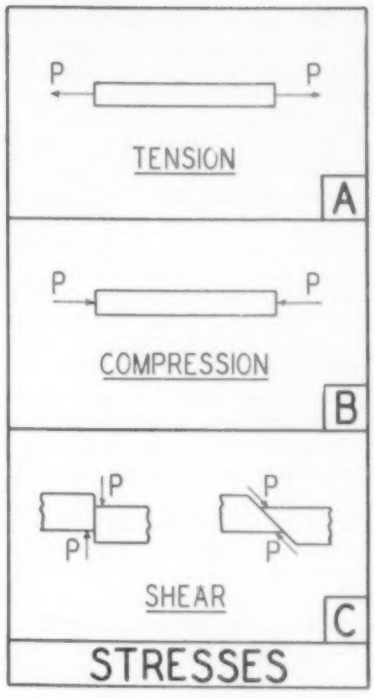


Fig. 1

	Engineering Practice	Am. Soc. for Test. Mat.
Internal force	Stress	.....
Intensity of internal force	Unit Stress	Stress

For engineers to adopt completely the second definition of stress as the intensity of the internal force leaves them without a suitable word for the force itself and they will undoubtedly be slow to abandon their use of the word stress to mean internal force. There is a clarity and exactness about the definition adopted by the A.S. T. M., but in this paper the author has chosen to follow the engineering practice.

Since both meanings of stress will be found in engineering literature it may be well to point out how qualifying words are helpful. When we say "stress in pounds" we are obviously talking about internal force. "Stress in pounds per square inch" quite as obviously refers to the intensity of the internal force. It is in this manner that ambiguity can be and is avoided.

The study of the distribution and behavior of the internal forces is a very complex subject, involving difficult mathematics, and there is no thought of introducing any of it here. In their everyday calculations, engineers do not go into all such refinements. This does not mean that engineers ignore the matter. Far from it. The distributions of these forces in ordinary structural members have been carefully investigated and evaluated so that suitable allowances can be made that will adequately meet the prevailing conditions. This is common practice in all fields of daily life.

Strictly speaking, there are three kinds of stress, first, the stress that causes an elongation of the material, to

which is given the name tensile stress; second, the stress that causes a shortening of the material, to which is given the name compressive stress; and third, the stress that causes a sliding action of one part of the material past another, which is designated as shear.

Stresses in structures arise from a variety of loadings and are sometimes referred to accordingly. They are not something that we can see and it will be easier to illustrate them by examples of loadings which produce them. In Fig. 1 we have examples of loadings which produce the three kinds of stress. The members in Figs. 1A and 1B typify those in which the stress is tension or compression. Either stress in a structural member is often referred to as a direct stress since the external forces that cause them act in a direction parallel to the axis of the member.

Figure 1C shows over-simplified examples of shear but they illustrate the tendency of one portion of the member to slide past the other. A familiar example of shear is the cutting of plates which, in shop language, is spoken of as "shearing."

These illustrations of stresses are wholly in line with engineering practice and are as far as the author should attempt to go in this paper. It is the business of engineers to know the more exact character of stresses and their behavior. Just an example to emphasize this point. Tension has been illustrated in Fig. 1A as the stress resulting from a pull P on the ends of the member. Within the member, the tensile stress is accompanied by a shearing force which reaches a maximum value on any plane at 45° to the direction of the tension. Along with the elongation in the direction of the pull goes a contraction at right angles to the pull, because the volume of the member changes very little. All such facts are recognized by engineers and are fully considered, but have been omitted here for evident reasons.

When we have beams as shown in Fig. 2 (A), the loads are generally acting transversely to the member. The stresses produced by the bending of the beams are commonly called "bending stresses" and will be quite thoroughly discussed in a later section, headed Bending. For the present it may be stated that the stresses are tension and compression. It is very rarely that we have bending without shear. If we take any location between a support and the load W we see that the upward reaction at the support tends to slide the beam in the opposite direction to the load. A beam, then, is an example of combined stresses.

It is a frequent occurrence to have various combinations of these stresses acting simultaneously in a member. Figure 2 shows a few of the combinations of loads that produce combinations of stresses. In the sketches of Fig. 2 (B) we have bending stresses produced by the load W combined with either tensile or compressive stresses produced by the axial loads P. The ordinary truss of a simple span bridge provides illustrations of these conditions. The horizontal top chord members are in compression while the bottom members are in tension. The weight of these members acts as a series of loads W to produce bending stresses. We may even have transverse loads applied directly to the chords by resting other members upon them.

In Fig. 2 (C) we have a combination of two tensions at right angles to each other, represented by P and R. We may have two compressions or a combination of tension and compression. Furthermore the stresses may act at any angle to each other. We also may have stresses acting in three directions, a case which is not shown in the sketches.

Still another combination of stresses is that shown in Fig. 2 (D) where the loads W and T bend the member in two directions. While the forces are shown at right angles to each other and to the beam, they may actually be at any angles.

We may consider the bending due to each load separately and so obtain the final result. The load W would deflect the beam vertically to a position indicated by the dotted line in the side view. When the load T goes into action it pushes the beam horizontally to the position of the dotted line in the top view. Of course, the deflections are much exaggerated in the two views in order to more clearly show the conditions. The cross section of the beam shown at the right of Fig. 2 (D) indicates the positions of the mid-span section after the loads have been applied and the lower left-hand dotted section is the final position of the beam.

The overhead traveling crane in any large shop affords an example of bending in two directions. The wheels at the end of the crane put vertical loads (corresponding to W) on the crane-runway girders along the side of the building. When the cross-wise trolley starts and stops in moving a load across the shop it exerts a force corresponding to the force T that bends the girder horizontally, or sidewise.

The combinations of stresses are almost endless in variety because of the number and sizes of the loads that produce the stresses. It is the task of the engineer to calculate these stresses and to proportion all the members and their connections so as to safely carry the loads.

Figure 3 shows some very obvious examples of simple stresses. The beams in the balconies support some vertical loads W that produce bending stresses in the beams. The balcony on the left is supported by a hanger

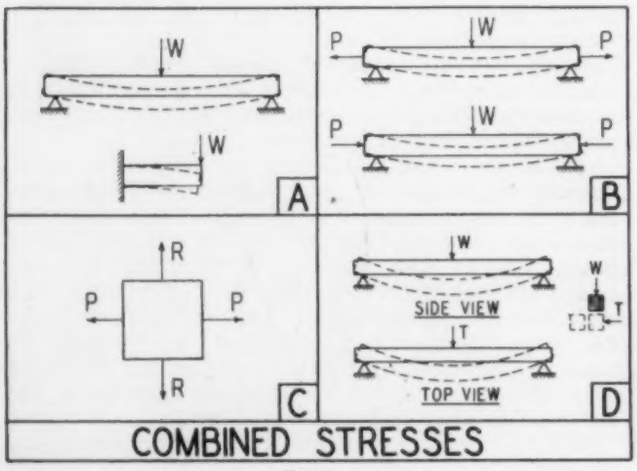


Fig. 2

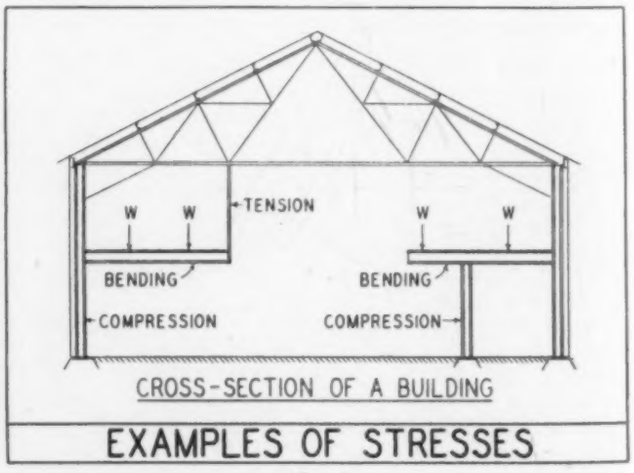


Fig. 3

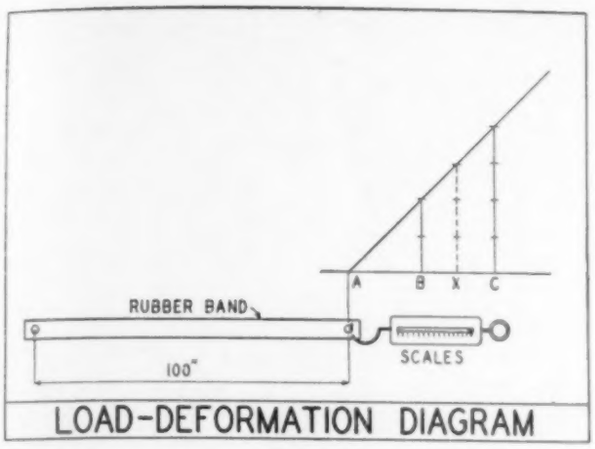


Fig. 4

from the roof truss and, clearly, the stress in the hanger is tension. When we support the balcony on a post or column (as shown for the right-hand balcony) we have compression in the post. The main building columns are in compression from the load from the roof trusses and from the balcony loads. Not all stresses are so evident or so simple to calculate.

Steel

The first step in any design is to decide upon the material of construction, whether it is to be steel, wood, reinforced concrete or a combination of all three. Whichever one is selected, the engineer must know its particular characteristics and manner of behavior. It is appropriate, therefore, that before taking up the subject of welding structural steel, we should review some of the characteristics of steel in which an engineer is particularly interested and which will help to explain more clearly some of the welding problems to be considered in later portions of this paper.

Let us approach the subject of the characteristics of steel by first performing an experiment with a rubber band as shown in Fig. 4. We shall start with a band having an initial length of 100 inches. The left-hand end is firmly anchored and on the right-hand end is attached a spring balance, or weighing scales. With the band straight, but with no pull on the balance, let us mark a starting point at A. When a load of 2 lb is applied by pulling on the balance we find that the initial point on the band has now moved to point *B*—in other words, the rubber has stretched. In the language of the engineer, the internal pull in the rubber is the stress and the unit stretch is called the strain. For a record of what happened let us draw a vertical line at *B* and measure up two units on some convenient scale to represent the 2 lb. of pull. Next we increase the pull to 4 lb. and the rubber band stretches to point *C*, where we erect another vertical line and mark up four units. This procedure can be repeated until we have stretched the rubber to several times its original length, but we will confine ourselves to a stretch of say 50%. By drawing a line through the points on the vertical lines we have what is known as a load-deformation djagram. We discover that this line is straight. From such a diagram we can read the load for any given deformation, or the reverse, without actually performing the experiment. As a simple example, suppose we wish to know the load that will be required to stretch the band to a point *X*, halfway between points *B* and *C*. At *X* we could erect a vertical line and, with our scale, measure up to the line through the points we determined by test, where we would read three units, meaning a load of 3 lb.

As we let off the pull, we find that the band shortens and if we stopped at the same points as when we increased the load and measured the loads on the vertical lines we would see that they were identical. Finally, with no load our initial point would be back at *A*.

It will at once occur to the reader to ask what would happen with a thicker rubber band. Certainly if the experiment were performed again we would have different results. If two bands of the same size were connected together side by side we would expect to have to pull twice as hard to stretch the combination to the same amount. We need some basis on which to compare bands of different sizes and the universal practice is to take the load on the basis of so many pounds per square inch. It is always possible to measure or compute the cross-sectional area of the piece of material that is to carry the stress. If our first rubber band had an area of 1 sq. in., a pull of 4 lb. on the spring balance would produce a stress whose intensity would be 4 psi. This intensity of stress is called *unit stress*—a term that occurs repeatedly in all engineering and should be thoroughly understood. Just to make this point clear, let us assume that the two bands have a total area of 2 sq. in. It would take 8 lb. to stretch them the same amount as the 4 lb. stretched the one band. In this case, the unit stress equals 8/2, or 4 psi. Thus, by always converting the internal force or stress to pounds per square inch, we can compare members having different areas.

The next query that would arise might well be—"What about different lengths of rubber bands?" Here again we need a common basis for comparison and the one used is that of per cent. When we refer to the stretch or strain in terms of per cent of the original length we have eliminated any confusion about differing lengths.

These bases require us to do a little figuring before we draw our stress-strain diagram so that the distances from point *A* represent percentages of elongation and our vertical measurements represent unit stress in pounds per square inch. This explanation has been perhaps un-

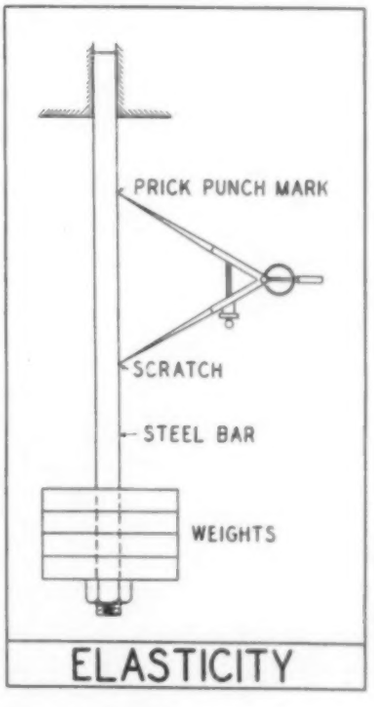
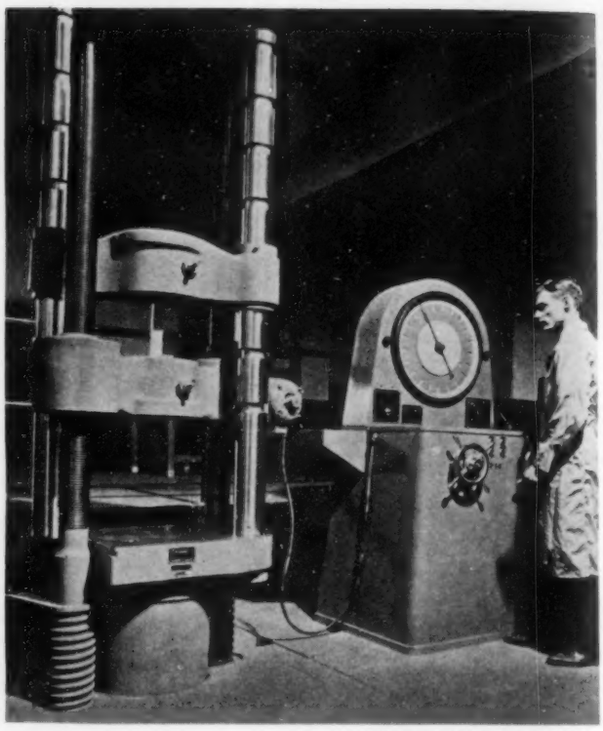


Fig. 5

duly long, but we need to fix these terms in our minds in order to understand the stress-strain diagram of steel and its importance to an engineer in his design and in his study of welded connections.

A casual inspection of a steel bar would hardly incline one to think of its being elastic. However, steel is definitely so and this property is of vital significance. Before discussing the stress-strain diagram for steel, let us consider another experiment with a soft steel bar replacing the rubber band shown in Fig. 5. The upper end of the bar is securely anchored and we shall apply the load by adding weights to the lower end. We shall select a portion of the bar to watch for the stretch, but this time, however, we shall need a microscope, as there will be no such stretch as we found with rubber. Before we apply the load, let us set one leg of a pair of dividers in a small prick punch mark and scratch a line on the bar at the other leg. The spread of the dividers becomes the length in which we are interested for the moment. After so doing, let us apply a relatively light load. This causes the bar to stretch a definite but small amount. As the load increases, the bar continues to stretch and if we look closely with a magnifying glass we may be able to detect that the point of the dividers is no longer in the center of the scratch line. When sufficient load has been added we shall notice suddenly a marked increase in length, so pronounced that we need no microscope to see it, and the increase will continue for a time without the addition of any more load. Then the bar appears to gather strength again and recover from its rather surprising action. More load can then be applied but the elongation will be more pronounced until finally the bar breaks. One might almost liken the bar to a fighter, who went along through the early rounds, without trouble, only to run into a punch that momentarily staggered him and weakened his resistance as he hung on in the later rounds until he was finally knocked out. In other words, our bar of steel acts like rubber up to a certain point, commonly called the yield point, then it takes on entirely new properties.

Now we come to the stress-strain diagram. It may be of passing interest to see in Fig. 6 a photograph of a modern testing machine. The machine is essentially a large weighing scale that indicates the pull on the test specimen. The bar to be tested is clamped securely on each end in the jaws of the machine and pulled until the bar breaks. By means of a sensitive instrument known as a strain-gage we can measure the elongation. A series of observations are made and recorded in which we have the loads and corresponding elongations. Simple calculations convert these data into stress (pounds per square inch) and strain (inches per inch, or per cent elongation). In the interest of uniformity, so that everyone will be talking about the same thing, there are standard forms of test specimens from which this information is obtained.



Courtesy Baldwin-Southwark

Fig. 6

In Fig. 7 is shown the standard specimen with an 8-in. length in which the final elongation is measured. Now, in effect, we can imagine that we stretch the steel bar just as we did in the experiment with the rubber band. Only a small portion of the whole diagram is shown, but it is the most important part for an engineer. A stress of

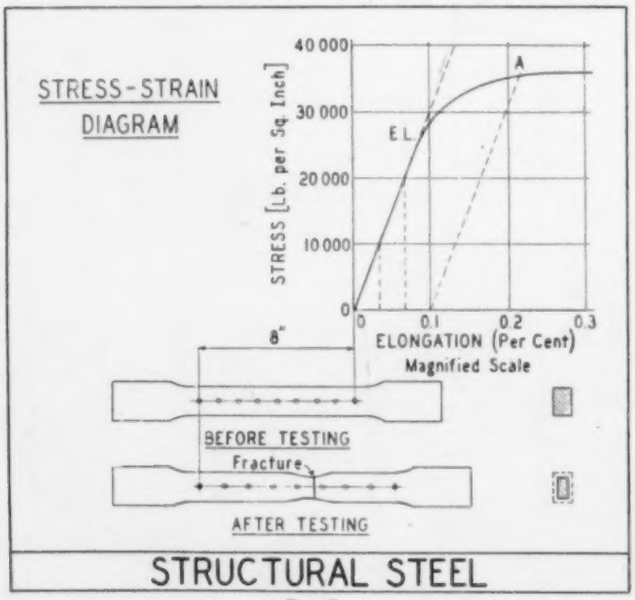


Fig. 7

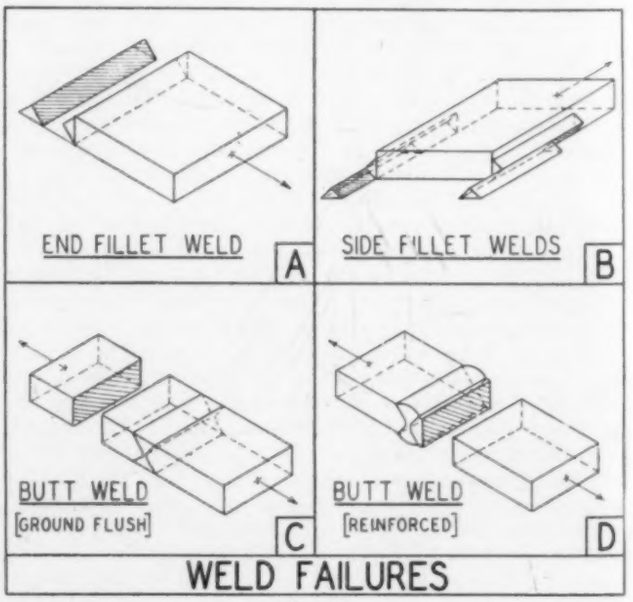


Fig. 8

10,000 psi. gives an elongation of one-third of 0.1%. Twenty thousand psi. increased the elongation to two-thirds of 0.1% and, from our experience with rubber, we might almost expect that for a stress of 30,000 psi. we will have an elongation of 0.1%.

Instead, the elongation is more. When we draw the line through the plotted points it is straight for the first part but begins to bend away from the straight line at a point marked *E. L.*—commonly referred to as the elastic limit. On this particular diagram we see that the elastic limit is at 28,000 psi. If we continue our observations of loads and elongations we find that the elongations increase rapidly and soon they are increasing with no increase of load. That occurs in the vicinity of point *A*, and the stress at that particular stage is known as the yield point strength, or more commonly, just the yield point. We note that this is about 36,000 psi. on our diagram. Specifications for ordinary structural steel contain the provision that the yield point shall not be less than 33,000 psi.

Another fact about the diagram must be noted. If, in the course of bringing the load up to the elastic limit we had released the load, the bar would have returned to its original length just like the rubber bands. But when the load exceeds the elastic limit we find that, unlike rubber, a permanent set has been given to the bar. When, for example, we released the load at point *A* we would find that our plotted points of stress and elongation would lie along the dotted straight line, which is parallel to the original straight line below the elastic limit. At zero load we would still have an elongation left in the bar of 0.1% and this extra elongation is called "permanent set." The exact position of the yield point is rather difficult to define but it is often arbitrarily taken as the stress that results in a permanent set of 0.1%.

Let us think for a moment of an elongation of 0.1% in terms of length per inch. For 1 in. of length the elongation is $^1/_{1000}$ of an inch. (For an 8-in. length it would be $^8/_{1000}$ in.) It will be found useful to remember that yield point stress produces this seemingly minute elongation.

The remainder of the diagram is not shown but if we continue to load the specimen we reach a maximum load at which the steel stretches rapidly in some local spot and then fractures. This rapid stretching results in a "necking down" of the steel and the final cross section is much reduced over its original size, as indicated in the section to the right of the specimen after testing. This maximum load is divided by the original area of the cross section to give us what is known as the "tensile strength."

As a result of many tests and of years of experience with structural steel the industry has established a specification that calls for the following limits within which the physical properties we have been discussing must come.

Tensile strength = 60,000 to 72,000 psi.
Yield point (min.) = $^1/_2$ of tensile strength but not less than 33,000
Elongation in 8 in. (min.) = $\dfrac{1{,}500{,}000}{\text{tensile strength}}$
Elongation in 2 in. (min.) = 22%

The steel mills are required by specifications to cut certain samples for test specimens from the steel plates, shapes, etc., that they roll for use in structural work. Let us assume that the testing laboratory reports as follows on a section taken from a beam.

Tensile strength = 69,400 psi.
Yield point = 36,900 psi.
Elongation in 8 in. = 25%
Elongation in 2 in. = 27%

Evidently the tensile strength is satisfactory. One-half of the tensile strength is 34,700 and the reported yield point is therefore satisfactory since it exceeds this figure and also the minimum of 33,000. According to the specifications, the minimum allowable elongation in 8 in. is $\dfrac{1{,}500{,}000}{69{,}400}$ or 21.6%—also exceeded by the test results. The elongation in 2 in. is above the minimum permitted. On the basis of the laboratory report, this steel meets the physical requirements and would be accepted for use.

Now what does all this mean to an engineer and how does he use the information. First of all, he is interested in the fact that steel is elastic in behavior when loaded up to a state of high stress. In later portions of this paper we shall have added proof of the elastic action of steel. From the standpoint of design, the yield point is probably the most important item, since it is the beginning of permanent set and of much greater elongations in the steel. No one would want a structure that warped out of shape under the loads that it was designed to carry. The yield point, then, becomes the upper limit of effective strength in an engineer's calculations. In practice, he uses what are known as working unit stresses that are obtained by dividing the yield point stress by a factor of safety, usually about 1.65 for structural steel base metal.

A simple example in design will illustrate the procedure. Let us assume that we have a load of 40,000 lb. that we wish to support by a hanger of steel. Since our specifications state that steel with a minimum yield point of 33,000 psi. will be acceptable, we must expect occasionally to get some steel that just meets this requirement and no more. Hence, if we are to be always on the safe side we shall apply our factor of safety to the minimum value in order to obtain our working stress. Accordingly, we divide 33,000 by 1.65 which gives us 20,000 psi. For the load of 40,000 lb. we shall need a hanger with a cross-sectional area equal to $\dfrac{40{,}000}{20{,}000}$, or 2 sq. in. Then each square inch will have a unit stress of 20,000 psi. which is the result we desire.

Welding Design

The primary function of welding is to unite various pieces of steel so that they will operate as a united structure to support the loads to be carried. If pieces must be held together, it means that there are forces tending to separate or pull the pieces apart. These forces have to be restrained or held by the strength of the welds. The engineer must know how to calculate these forces and the resulting stresses and understand their behavior under conditions which prevail in welded construction. Strength of welding becomes the first essential of design. In everyday life, we are unconsciously applying the criterion of strength in many situations. We do not use string where a rope is required, nor would we walk across an opening on a board where a plank was needed.

Before reaching any conclusions as to how to design for welding it is essential that we know the manner in which welds fail under varying kinds of loading. When a weld fails under the action of a load it does so by shearing or tearing apart along the plane of least strength or resistance. In Fig. 8 are shown several typical examples. The end fillet weld of sketch A is representative of those that lie across the line of pull indicated by the arrow, such as welds at the ends of cover plates. These welds

usually pull apart along a diagonal plane that has a minimum cross-sectional area called the throat area. This is not surprising, since it might be expected that failure would occur at the weakest spot. Fillet welds are very often placed parallel to the pull as shown in sketch B, such as the side welds of a cover plate. Here again failure occurs on the diagonal plane of least area. In the case of butt welds that lie across the line of pull, the failures may be influenced by whether the reinforcement is ground flush or left on the weld. For the example in sketch C, the failure most often occurs at a point in the base metal some distance from the weld since the weld metal is often stronger than the base metal. The reinforcement introduces a factor of stress concentration that may contribute to failure close to the weld. This subject of stress concentration will be more fully treated in a later section of this paper.

Just as we determined the strength of steel in terms of pounds per square inch, so the strength of welds is expressed in the same terms. These unit stresses in the welds are based upon the areas of the sections at which failure in the welds occur. For fillet welds, this is the area of the throat, which is the minimum area. In the case of butt welds, we find that failure often occurs in the base metal and we therefore use the cross-sectional area of the base metal. When the two parts to be butt welded are of unequal thickness, it is the practice to use the area of the thinner part.

From a long series of tests and experience there have been developed the strengths of various kinds of welds and the proper factors of safety to be used. From these two items have resulted the basic working unit stresses upon which designs are made. Structural welding embraces a wide field of structures, ranging from those carrying stationary or quiescent loads, as in buildings, to those that are subjected to impact or repeated variations in the load, as represented by bridges. Buildings that support machinery and even the machinery itself may come in an intermediate classification. It all depends upon the amount of impact and repeated action that is present.

The design specifications of the AMERICAN WELDING SOCIETY will illustrate the variations in working unit stresses according to the type of construction. There are the Code for Fusion Welding and Gas Cutting in Building Construction and the Specifications for Welded Highway and Railway Bridges. It is not feasible to make a detailed analysis of the requirements of the two specifications, as they are readily available through the SOCIETY for those who may wish to study them more carefully. An example will illustrate the differences in the working stresses allowed for a building and for a bridge.

According to the Building Code a fillet weld is permitted to carry a shearing stress of 13,600 psi. on the throat of the weld. The Bridge Specifications allow only 9600 psi. and have an additional formula that reduces the unit stress to 7200 psi. when the stress varies from zero to a maximum and then reduces the unit stress even further when the stress varies from tension to compression in a repetition of the loading. The Building Code permits a tension on the throat of a butt weld equal to 16,000 psi. and the Bridge Specifications allow the same unit stress unless the load is varying, causing a variation in the stress. When the stress varies from zero to a maximum, the working unit stress for a butt weld is reduced to 13,500 and still further when alternations between tension and compression occur.

This paper is not intended to be a discussion of designing methods, but it may add to the general picture if a simple example is included to illustrate the method by which an engineer determines how much welding is

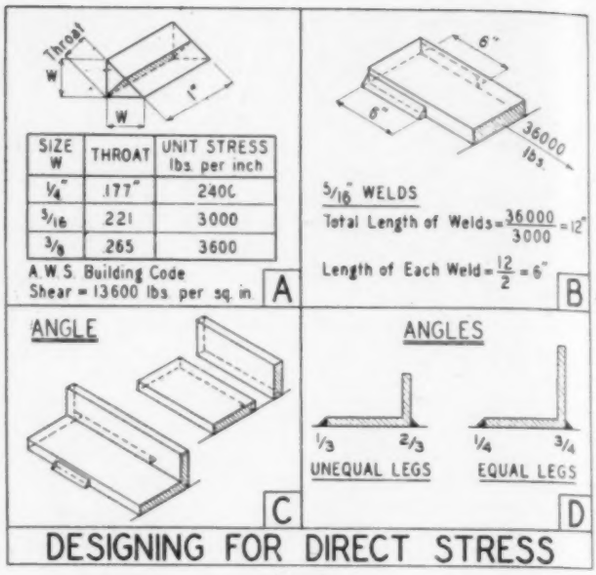


Fig. 9

needed at a joint. In Fig. 9 we have all of the steps in the design of a joint made with fillet welds. The sketch in Fig. 9 (*A*) shows a fillet weld of 1-in. length. The size of the weld is designated by the length *W* of the leg of the fillet. The shortest dimension of the fillet cross section is the throat. Engineers have found it necessary to use fillets welds of various sizes and for convenience and rapid use a table of strengths is generally prepared. Such an abbreviated table is shown in the sketch. When dealing with fillet welds it has been found more convenient to think of the unit stress in pounds per linear inch, although the value is obtained from the unit stress in pounds per square inch. As an illustration, the throat dimension for a $^5/_{16}$ weld is 0.221 in. For 1 in. length of weld the throat area equals $1 \times 0.221 = 0.221$ sq. in. Using the unit stress of 13,600 psi. permitted by the A.W.S. Building Code we obtain a unit stress of $0.221 \times 13{,}600 = 3000$ pounds per inch.

For our problem let us assume a bar having a tension load of 36,000 lb. (see Fig. 9 (*B*) for which we shall provide the proper amount of $^5/_{16}$ fillet welds to connect the member. Each inch of a $^5/_{16}$-in. weld can safely carry a stress of 3000 lb. per inch. Hence we shall need $\frac{36{,}000}{3000} = 12$ linear in. of welding. Since the bar is a symmetrical member we shall divide the welding equally between the two edges parallel to the axis of the bar, making 6 in. on each side. We might have put some of the welding across the end and shortened the side welds by an equal amount. It is desirable, however, to have a good proportion of the welding distributed on the sides.

The angle is a very common structural member and presents an unsymmetrical section, in contrast with the bar. We may think of an angle made up of two bars as shown in Fig. 9 (*C*). The welding of the horizontal leg would be handled in the same way as for the flat bar. The vertical leg would require welding to connect it, too. When the vertical leg is restored from its imaginary position to its actual position in the angle, the welding would have to be added to the welding on that edge of the flat bar. So in an unsymmetrical member we get more welding along one edge than another. For the usual sizes of angles in structural work the approximate distribution of welding will be very close when made as indicated in Fig. 9 (*D*). There have been some investigations that indicate that perhaps the welding should be distributed

equally on the two edges of angles but tests have not fully confirmed this procedure.

Having determined the amount of welding, the engineer next has to see that there is room to place the required lengths, making due allowances for clearances and accessibility. In fact, it is the careful attention to these factors which makes for a good job and the kind of planning which facilitates the welder's part of the work. The welder may not always have realized why some jobs seemed to go along smoothly, but many times, no doubt, it has been due to the study and foresight of the designing engineer.

Stress Paths

Some knowledge of stress transfer through welds is most desirable and possibly will explain why engineers are so concerned over proper penetration and the surface conditions of welds. Early in the paper the term stress in engineering practice was illustrated by the example of one man pulling on the end of a rope and his pull being transmitted through the rope to a man at the other end. Stresses may be thought of as traveling, much as human beings travel, and their behavior has some rather striking similarity to human actions.

There is a principle of engineering known as the theory of least work. All nature follows that principle. Anyone who owns a corner lot will confirm the fact that people will cut across the corner, if only to save perhaps two extra steps. Now stresses have that same exasperating habit. Or again, any baseball fan knows the result at the turnstile when the flow of humanity toward the gate meets the restrictions of the narrow openings. Stresses will behave in a similar manner when their path is suddenly changed in width.

In Fig. 10 (*A*) we have a smooth flat bar with a force *P* applied to either end. The stresses flow uniformly through this bar as represented by the light lines drawn on the upper half of the sketch. We have no unusual conditions of stress travel. It is like a straight, open road.

Conditions are different in Fig. 10 (*B*) where there is an abrupt change of section and the stresses which were traveling along uniformly in the wide portion suddenly find their path constricted. At the expense of strict accuracy we may draw a helpful analogy. Stresses cannot hold back in an attitude of "After you, my dear Alphonse," but all rush along together. Naturally, there is a traffic jam and at the sharp-angled corners a dangerous situation arises. The stresses may become so concentrated as to pull the steel apart and start a crack that will lead to failure of the entire bar. The condition can be very greatly relieved by rounding the corners, as shown in Fig. 10 (*C*), and the larger the radius of the curves, the smoother will be the flow of stress, with a resulting lower concentration. Have you noticed how the curbs of busy streets are being rounded to facilitate the flow of traffic around corners?

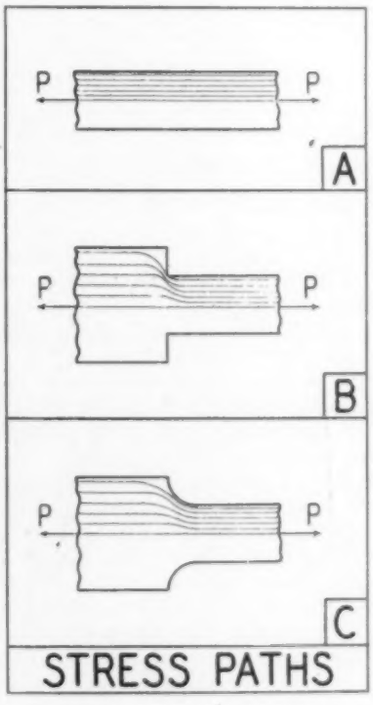


Fig. 10

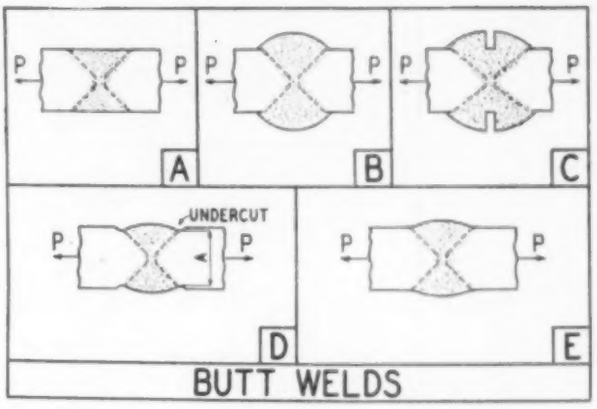


Fig. 11

When we place a butt weld in the stress path, as we might by splicing two bars together, it is essential to know how the stresses are going to act, in order that we can design a joint that will safely allow the stresses to pass through. For the case depicted in Fig. 11 (*A*), with the welds ground flush, we have practically the condition of a plain bar and the stresses are distributed uniformly over the cross section. But suppose we have the condition shown in Fig. 11B with an exaggerated amount of weld reinforcement. When the stresses arrive at the weld, they find a rapid expansion of their path at the edges of the weld. An expansion is simply a contraction in reverse and the result is a tendency for the stresses to pile up or concentrate at the corners, as in Figs. 10 (*B*) and 10 (*C*).

Some one may wonder why any stress needs to flow out through the reinforcements when there is still the straight, unobstructed path that exists in Fig. 11 (*A*). The explanation is quite simple. When we were discussing the subject of steel, we saw that steel is elastic and elongates under stress. Let us consider Fig. 11 (*C*). When the bar is stressed the weld itself is stressed and elongates or stretches. If the reinforcements were to carry none of the stress, they would have to open up as shown. Clearly, such action is impossible and the only alternative is for the reinforcement to stretch also. It takes just as much stress per square inch to do this as in that portion of the weld itself that lies directly in the path of the bar.

Figure 11D is the opposite of Fig. 11 (*B*). Here we have an insufficient amount of reinforcement with an undercut which restricts the stress path. The previous discussion makes it clear why this condition is undesirable. Apart from the stress concentration that may occur at the corners, we may actually have less cross-sectional area through the undercuts than in the main

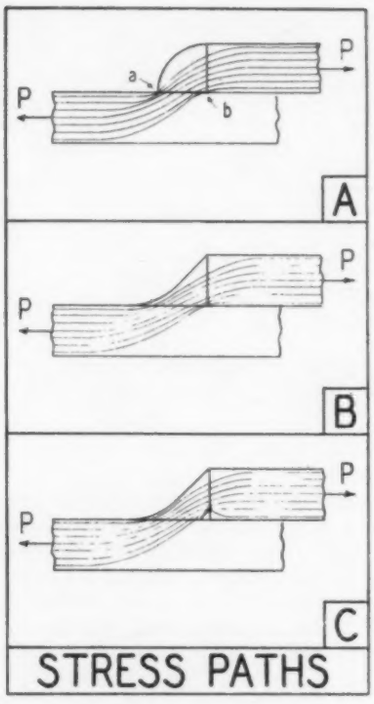


Fig. 12

body of the bar. A rough surface to the weld produces ridges and depressions with rather sharp corners that can and do provide stress concentrations—sometimes serious enough to be the source of cracks. The ideal type of butt weld is shown in Fig. 11 (*E*) in which smooth stress paths are provided and concentrations are minimized.

In Fig. 12 (*A*) we have a fillet weld with an excessive amount of reinforcement. As the stresses flow from one bar to the other, they tend to take the shortest path—the path of least work. One can readily see that points *a* and *b* are locations where the stresses are going to be crowded together. We have seen that sharp corners are greater stress raisers than those with generous radii or fillets. The excessive reinforcement creates a rather sharp angle at point *a*. This condition can be relieved by the smooth curve at the toe of the weld shown in Fig. 12 (*B*). We can still have sufficient strength through the throat of the weld, which is the critical section in fillet weld failures.

A serious condition can arise at point *b* when there is lack of penetration at the root of the weld as shown in Fig. 12 (*C*). If there is no penetration or attachment between the weld and the plates at the root, it is actually the same as an absence of any weld there. Under such circumstances, one can readily visualize the stress concentration in the region of the root.

We may have internal stress raisers as depicted in Fig. 13. If, as in sketch A, we drill a hole in the bar, we force the stresses to divide and go around the hole just as water flows around a bridge pier in a river. From the traveling habits of stresses, we know that there will be some congestion or concentration of stress but the curved edges of the hole will greatly reduce the effect. Of course, it is possible to drill such a large hole that the remaining cross section of the bar at the hole lacks enough area to carry the full load without failure. The counterpart of the drilled hole is to be found in welding wherever a cavity, or gas pocket, occurs.

When we cut a rectangular hole in a bar, as in Fig. 13 (*C*) we have the same restriction of the stress path but the sharp corners of the hole cause much higher concentrations of stress. Such a condition can easily arise in a butt weld of the type shown in Fig. 13 (*D*). The incomplete penetration leaves a rectangular opening in the stress path that might be the cause of a failure in the joint.

The stress paths around the holes of Fig. 13 are shown in Fig. 14. There are the usual concentrations at the edges of the holes where the stresses seem to hug the inside edges of the paths. Investigations have shown the unit stress at these points of concentration can be 2 to 3 times the average unit stress in the steel and in some cases even more. Engineers speak of such a condition by saying that the stress concentration factor equals 2 to 3.

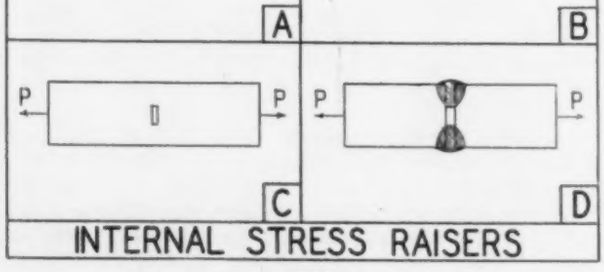


Fig. 13

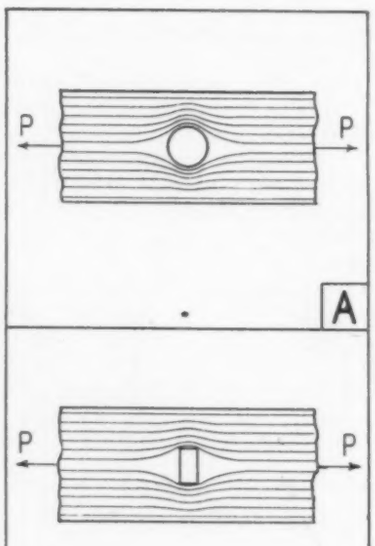


Fig. 14

Many specifications restrict, or prohibit altogether, the use of connections welded from one side and the reasons for so doing are evident from this previous discussion. In the butt-welded joints of Fig. 15 (*A*) we have stress paths that are similar to Fig. 10 (*B*) with sharp corners that give high concentrations which easily lead to initial cracks and eventual failure. Figure 15 (*B*) shows a joint that is subject to concentration of stress from an upward pull on the vertical bar or from a horizontal force acting toward the left to tip the vertical bar over. It is a poor type of connection. Such a one-

sided connection as is depicted in Fig. 15 (*C*) is subject to a bending action, due to the eccentricity of the joint. It will be observed that this bending pries the weld in a way to cause tension across the root of the weld. We have seen that the root is a potential source of difficulty and a condition such as that of Fig. 12 (*C*) would have a serious effect on this one-sided connection.

The stress concentration at a sharp notch is often utilized when we wish to break some material at a definite location. The glazier scratches a line with a diamond or steel wheel on a piece of glass to make it break at the line. We "notch" a stick or nick a bar of steel to facilitate its breakage. All such operations take advantage of the greatly increased stresses at a sharp notch and are evidence to bear out the investigations of engineers.

It must be clear by now why engineers have been concerned over such apparently small details of a weld as its shape, position and penetration. Fortunately, for all concerned, the situation with structural steel is not so alarming as it sounds. The ductility of structural grade steel steps in to modify the effect of these stress concentrations. When the steel is first stretched, there may be some points of stress concentration where the unit stress reaches the yield point. When this occurs, the high stresses will be prevented by the yielding of the steel and a more uniform distribution will take place, thus modifying the seriousness of the situation.

We should not leave this subject of stress paths and stress concentrations without a word of caution and assurance. To have knowledge about the behavior of welds is to be forearmed in dealing with them. It should be remembered that the working unit stresses which engineers use are based upon many tests of actual welded joints. We have seen, for example, that fillet welds have a stress path that is productive of stress concentrations, but that effect has been present in the tests, and the final strength of the test joints has been influenced accordingly. The fillet weld is a very useful one and very widely employed and we need only to recognize its particular peculiarities and make the necessary allowances for them. Knowing that good root penetration and the avoidance of sharp-cornered toes on such welds are important factors, we should always strive to achieve these desirable results. Each type of weld has its individual characteristics and requires individual consideration.

A sense of balanced judgment needs to be exercised in dealing with defects. It is not so much the mere existence of blowholes, for example, that is important, as their size, location and the number that exist within a certain length or cross section of the weld. In such structures as pressure vessels, it is so important to have knowledge concerning interior defects that the specifications for several types of these vessels require every weld to be examined with X-rays.

The service to which a structure is to be subjected has a bearing upon this subject. In those that carry only steady loads, slowly applied and removed, as in an office building, warehouse or hospital, the matter of stress concentration is not so vital as would be the case where impact and repeated stresses are present as in bridges, cranes, derricks and material-handling machinery. All such factors are properly taken into account by an engineer when designing any structure. After preparing his plans, he expects that the welder will exercise the same care to produce welds of satisfactory quality. The engineer is expected to bring his best knowledge and skill into the design and the welder has the same opportunity, as well as need, for exercising his particular skill. In both cases, the greater the knowledge of all phases of welding, the better able are both engineer and welder to cooperate in achieving a fine structure.

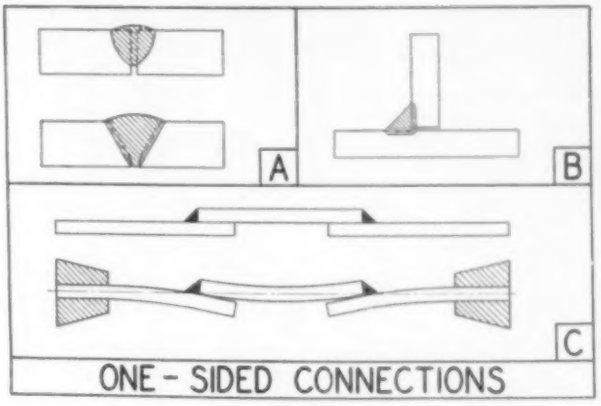


Fig. 15

Bending

We have been considering what are commonly called "direct stresses," resulting from a pull or push along the axis of a structural member. Bending action produces similar stresses of varying degree which, in many ways, are much more interesting because of the variety of their manifestations or occurrences. This very variety adds to the complications in dealing with them and calls for a thorough knowledge of their behavior. In the short space of this paper it is quite impossible to do more than touch upon important phases of bending action.

Just as engineers speak of the direct load in pounds or the unit stress in pounds per square inch, so they have the term "bending moment" to designate the measure of the bending action. This bending moment is easily understood if we take a simple illustration. Figure 16 (*A*) represents a cantilever beam, a common example of which is the diving board at any swimming pool or bathing beach. Using Fig. 16 (*B*) as an example, let us assume the board to be 8 ft. (96 in.) long and that a 200-lb. man is about to dive. As he walks out on the board we are aware that the board is "bending" and that this bending increases to a maximum when he reaches the outer end. Engineers know that if they multiply the weight of the load by the distance of the load from the support, they have a product (called bending moment) that enables them to calculate the bending stresses. In our assumed example the moment at the support, commonly designated by the letter M, is

$$M = 200 \text{ (lb.)} \times 8 \text{ (ft.)} = 1600 \text{ ft.-lb.}$$
$$M = 200 \text{ (lb.)} \times 96 \text{ (in.)} = 19{,}200 \text{ in.-lb.}$$

It is obvious that the support of a cantilever beam must provide some anchoring means of resisting this bending moment. Two methods of accomplishing the desired restraint are of interest to structural engineers. One is that of extending the beam back beyond the support, as in Fig. 16 (*C*), to provide a counter-balance. We see examples of this method in many theaters and auditoriums, where the front of the balcony is really a cantilever beam, or beams, supported on columns or girders and anchored to the back of the auditorium.

The Empire State Building in New York City is an outstanding cantilever beam under the action of wind loads. In Fig. 17 (*A*) is shown an outline drawing of the building with the forces of the wind indicated by arrows. When we turn the sketch as in Fig. 17 (*B*) we see the direct comparison with Fig. 16 (*A*). Wind can be a potent force in producing stresses in structures and is always taken into account.

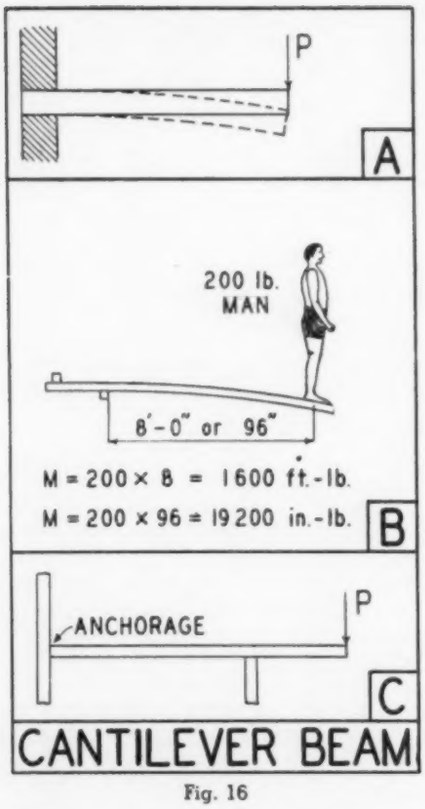


Fig. 16

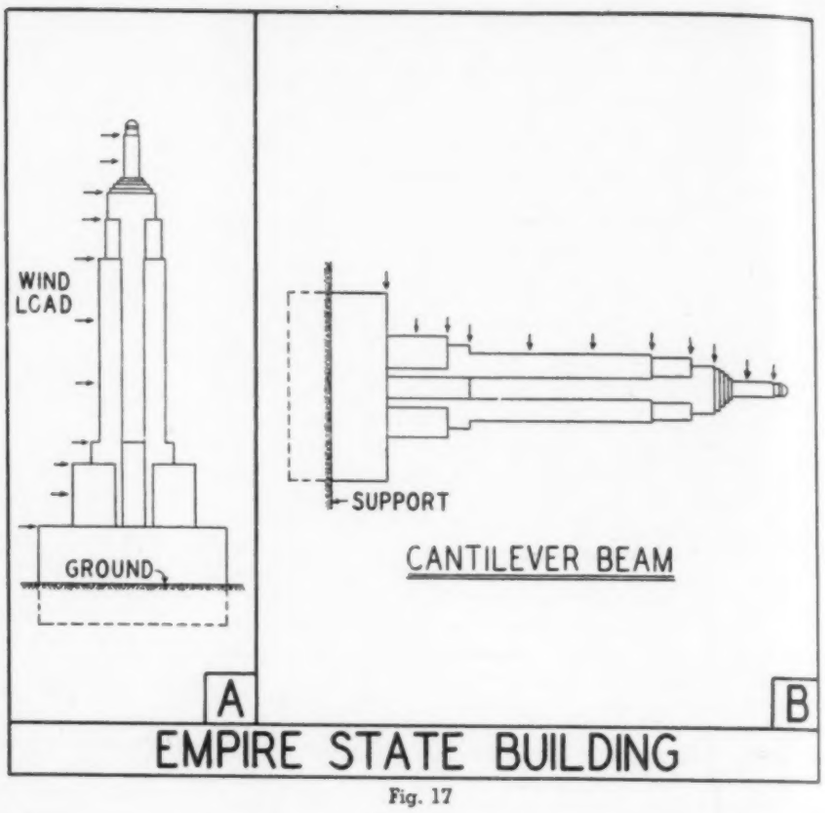


Fig. 17

The second method of resisting the bending moment of a cantilever beam is that of attaching the support end of the beam directly to some structure that has ample rigidity to provide the resistance. It is this method which holds direct interest for anyone concerned with welded construction. We find it in brackets attached to columns and, as we shall see presently, in a somewhat modified form in the end connections of beams to columns.

It is not within the scope of this paper to discuss the principles used in the calculation of bending moment. However, let us follow through one short calculation to illustrate the end connection of a cantilever beam. If in Fig. 18 we have a load of 10,000 lb. on the end of a 36-in. cantilever beam, the moment at the support is 10,000 × 36 = 360,000 in.-lb. Now the only grip on the beam is at the top and bottom flanges and, if the beam is not to rotate or fall, the forces F that are set up must balance the bending moment. With a 12-in. beam, for example, these forces are 12 in. apart and when we divide the bending moment in inch-pounds by the distance in inches between these supporting forces we get the amount of the forces.

$$F = \frac{360{,}000}{12} = 30{,}000 \text{ lb.}$$

Therefore we have to provide connections at the top and bottom flanges that will have the strength to carry safely these forces of 30,000 lb.

Now, of course, we must take care of the downward force of 10,000 lb. In addition to causing a moment at the support it also creates a shear, or tendency to slide the beam down the face of the support. Either we must make the bottom connection act as a seat angle or put a connection on the web. The details of a complete joint will be discussed under beam connections.

It is essential to have a clear understanding of the action of a beam under conditions of loading. In Fig. 19 (*A*), there is shown a beam with a single concentrated

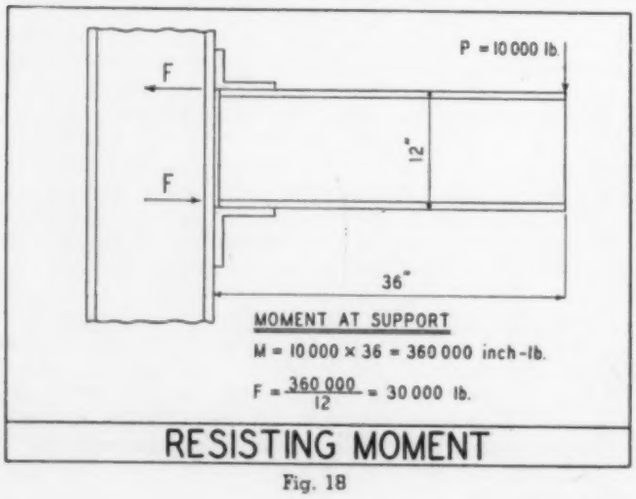


Fig. 18

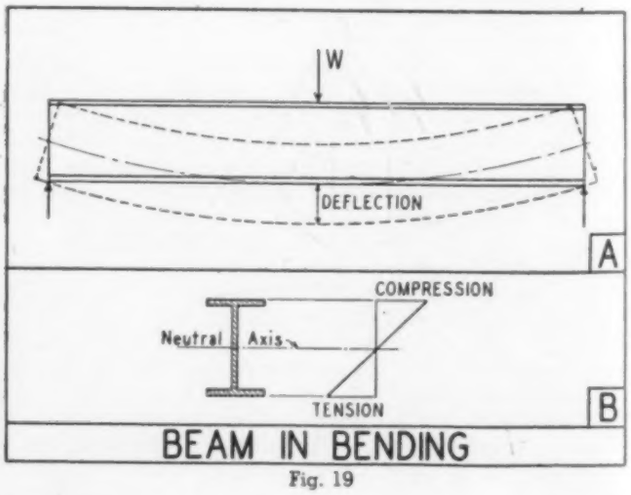


Fig. 19

load at its center. Before the load is applied the beam is in the position shown by the full lines and in the dotted position after the load is applied. The first point to observe is the rotation of the ends of the beams—a tilting inward at the top and outward at the bottom of the beam. This point is a very important one to keep in mind, as it is this rotation which creates a difficult problem for the designing engineer.

We observe also that the beam is deflected downward. A moment's thought will make it evident that the bottom portion of the beam between the supports is being stretched, that is, the material is in tension. Likewise the top is in compression. Hence, we have a beam with tension and compression on opposite sides. Evidently there is a point where the stress changes from tension to compression and must therefore equal zero. Engineers call this location the neutral axis—the word "neutral" implying that the stress is neither one nor the other. It may be stated as a fact that the stresses in a beam are maximum at the top and bottom and change gradually to zero at the neutral axis.

In Fig. 19 (*B*), we have the cross section of a beam and the diagram is a plot of the stress in pounds per square inch. Through certain formulas, the engineer is able to calculate the stresses in beams in terms of pounds per square inch—which are the same terms used when we were considering tension and compression as directed along the axis of a structural member.

It is important to keep in mind that when the material is under stress there is a deformation (elongation or shortening) and, conversely, if there is deformation there is a corresponding stress in the material. This fact enables engineers to find the stresses in any structure by measuring the deformation. By this means, they can study the distribution of stresses in structures where theory alone is not sufficient to solve the problem. There are cases in which the calculations are so involved and so many assumptions have to be made that it is well nigh impossible to arrive at the true stresses. For this reason engineers often supplement their design computations with laboratory tests on actual structures or structural members.

Returning to the ends of a beam, let us examine more closely the conditions which exist there. We have seen that in a simply-supported beam there is a definite

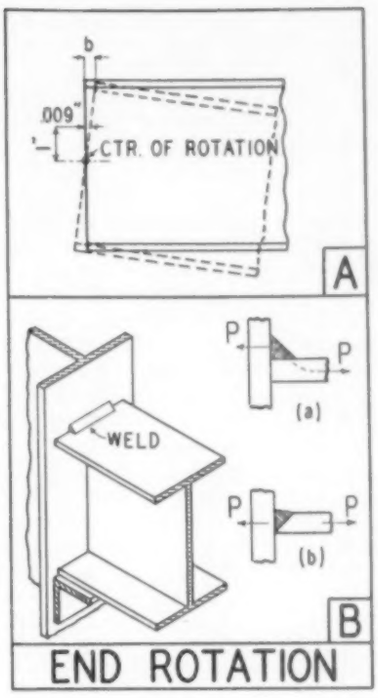


Fig. 20

rotation of the ends. Most beams in building construction carry loads that are uniformly distributed along the span. For such a loading condition the calculated rotation at the ends of the beam is shown in Fig. 20 (*A*). If we assume the center of rotation to be at the center line of the beam we have the displacement at the top equal to one-half of the depth in inches multiplied by 0.009 in. For an 18-in. beam, the movement at the top, b, equals $9 \times 0.009 = 0.081$ in.

Suppose we put a small amount of welding along the top flange with the idea of providing enough stability to hold the beam in line laterally, as indicated in Fig. 20 (*B*). When the end rotates, the weld begins to resist the pull and lacking sufficient strength to prevent the rotation, it is almost certain to crack. When the fillet weld

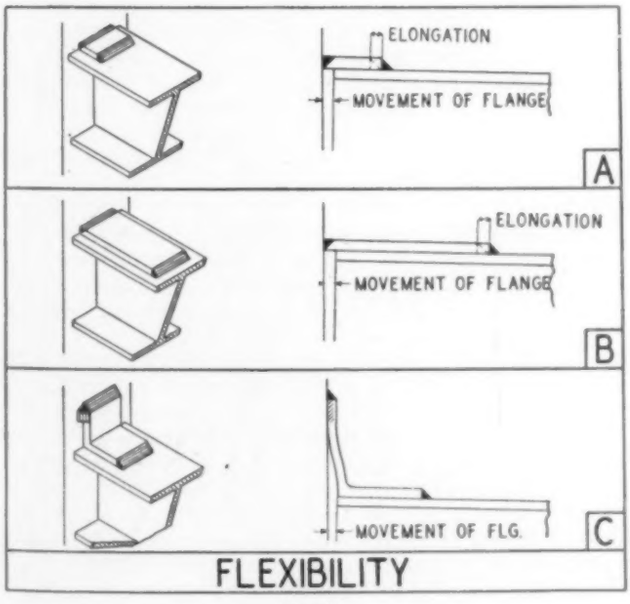


Fig. 21

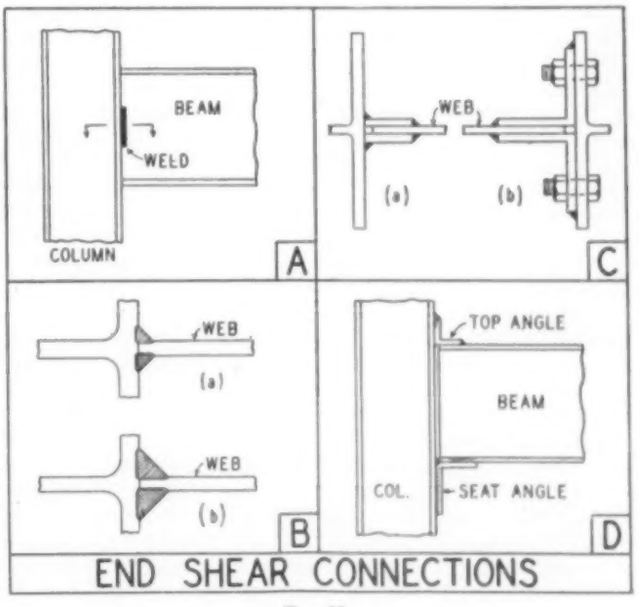


Fig. 22

of sketch (a) is used, the combination of the amount of elongation to be met and the stress concentration at the root of the weld can easily be too much for the weld to stand. The stress path in the butt weld of sketch (b) is more direct but here too, an insufficient amount of welding is an invitation to trouble.

This end rotation is a very positive factor and there is no compromising with it. Either sufficient welding must be placed on the joint to entirely resist the rotation or some adequate provision made to permit a partial or complete yielding of the connection.

Various methods have been proposed and used for meeting this situation. Evidently, the one shown in Fig. 20 (*B*) is inadequate. In Figs. 21 (*A*) and 21 (*B*) are shown two similar methods—the only difference being in the length of the top plate. When the top flange of the beam moves, due to the rotation of the end of the beam, the top plate is forced to elongate so long as the welds hold and, of course, the whole idea is based on the welds being strong enough. In the case of the short plate in Fig. 21 (*A*) the elongation per inch is high and we are well out on the horizontal portion of the stress-strain diagram of Fig. 4, well beyond the yield point at *A*. For a very short plate, we might even be beyond the point at which the steel begins to recover some of its resistance. The use of a longer plate in Fig. 21 (*B*) is an endeavor to spread the same elongation over more inches of length and so bring the percentage of elongation back nearer to the yield point, and the elastic portion of the curve. It is probably impractical to reduce the unit stress below the yield point because the plate would have to be too long.

Figure 21 (*C*) shows a common method of providing flexibility by using an angle connection and placing the welding as indicated. Such an arrangement permits the angle to open up, as shown in the section, and again relieve the welds of the full elongation. An important contribution to the subject of beam connections was presented recently by Bruce Johnston and Gordon R. Deits in their paper—"Tests of Miscellaneous Welded Building Connections"—preprinted for A.W.S. Convention October 1941 and later printed in the January 1942 issue of the JOURNAL.

It has already been pointed out that beams also have a shear, or end reaction, which must be transferred to the supporting structure. This shear is largely carried by the beam web and so we have to provide some connection to this web. It naturally comes to mind to put the welds directly on the web as shown in Fig. 22 (*A*). We might at once think of our calculations in Fig. 9 by which we determined the length of welds to carry this shear. This would be fine if it were not for the end rotation. Let us assume that our calculations indicated that 6 in. of $^5/_{16}$-in. welds were required on each side of the web. From the sketch in Fig. 20 (*A*) we see that for every inch away from the axis of rotation there is a movement of 0.009 in. Assuming the axis of rotation to be at the center of the weld, the total movement at the top of the weld would be 3×0.009 in., or 0.027 in. You think—"Why! That doesn't amount to much"—but when you recall that a stretch of 0.001 in. per inch requires a unit stress equal to the yield point of steel, you quickly realize that the pull at right angles to the weld is going to carry the stress in the weld, or in the web, or in both, above the yield point. What to do about that condition is one of the big problems with which engineers have been wrestling.

Two schools of thought advocate different solutions. One group says in effect—"Make the welds heavy enough that they won't fail and then force the web to do most of the stretching." Figure 22 (*B*) illustrates this method. The small welds of sketch (*a*) may be seriously overloaded but if the size is increased as in sketch (*b*) their strength may exceed that of the web of the beam, in which case the horizontal pull will overstress the web and force most of the required elongation into the web. From the practical point of view, a connection such as that of Fig. 22 (*A*) requires an accurate fit between the beam and column and is therefore not well adapted for construction. A means for getting around this difficulty is illustrated in sketch (a) of Fig. 22 (*C*), which is a section through the end connection. Bars are placed on either side of the beam web to bridge the gap between beam and column and these bars serve to transfer the shear.

The second group says—"Provide a flexible connection which can absorb the movement and so keep the stresses on the welds within reasonable limits." Flexible connections are obtained by the use of angles which act in a manner similar to the top connection we have just been considering. Such a connection is illustrated in the section of sketch (b) of Fig. 22 (*C*). The bolts shown in the sketch are those used in erection and are left in place to act as a restraint on the outstanding legs of the angles in bending. With this difference in viewpoints, it is clear why engineers are continuing to investigate the subject of beam connections.

In any of these flexible connections, the stresses somewhere in the connection are almost certainly at or above the yield point of the original steel. This is not a serious situation provided we keep the high stresses out of the welds that actually transmit the end shear, or reaction, of the beam.

Of course, if it is desirable to design the connection to fully resist the end rotation, we then have what is termed a fixed-end condition. This requires a large amount of welding and is a costly method. Therefore, engineers have been seeking a compromise solution and for a number of years the AMERICAN WELDING SOCIETY and the American Institute of Steel Construction have been jointly carrying out extensive tests on full-sized welded connections in the laboratories of several universities and at the National Bureau of Standards in Washington.

The discussion, so far, has not referred to the simplest way of carrying the shear or reaction to the supporting structure. Whenever possible, it is an easy matter to support the end of the beam on a seat angle or bracket and so avoid any welds on the web. Then if flexibility is provided in the top connection we have a condition shown in Fig. 22 (*D*) where it will be seen that the web is not restrained in its movement away from the support. Then the only bending action for which we have to provide is that produced in the seat angle by the load acting a small distance out from the support. Engineers have satisfactory methods for designing brackets for such conditions.

Temperature Effects

The behavior of steel with changes of temperature is of vital importance in welding operations. Because the effects due to welding are so complex, it may be helpful to consider first some of the effects on steel of temperature changes under controlled conditions

It is a well-known fact that, in general, substances expand in size and volume as the temperature increases and, conversely, contract as the temperature decreases. We use the greater expansion and contraction of mercury or colored alcohol, as compared to glass, in our thermometers to give us a measure of the temperature. Steel is no exception, but when dealing with the actual amounts of expansion or contraction with changing temperature, one has to get accustomed to very small figures. For example, at ordinary atmospheric temperatures, when the temperature of structural steel increases 1° F., each

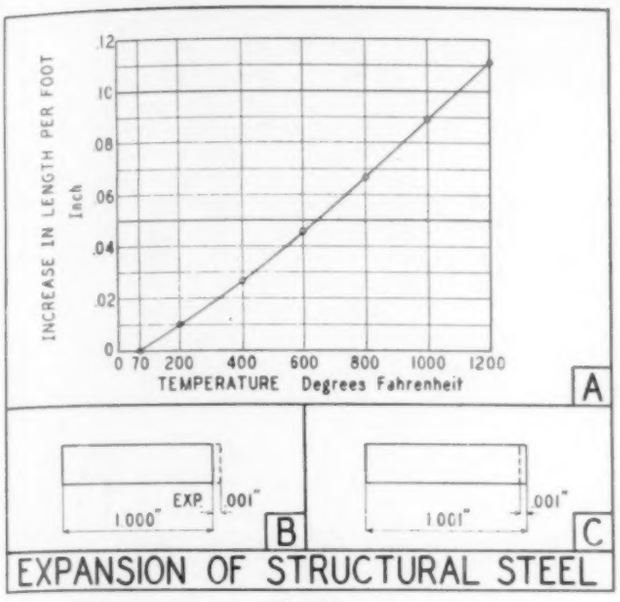


Fig. 23

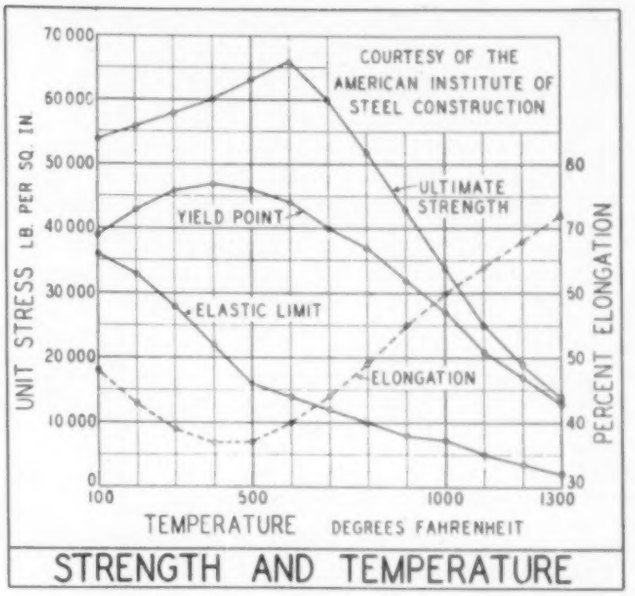


Fig. 24

inch of the bar increases 0.0000067 of an inch in length. That may seem almost negligible, but let us look into the matter a little further. It is not uncommon in a bridge structure to have a member that is 25 ft. (300 in.) long. In our climate, that bridge might be at a temperature of 20° F. below zero in winter and up to 130° F. in the summer sun, which is a change of 150° When we calculate the total change in length of such a member from winter to summer we get $300 \times 150 \times 0.0000067 = 0.3015$ in., or about $^5/_{16}$ in. The whole bridge expands at the same rate, while the earth between the supports changes less, making it necessary to provide expansion joints in all bridges to permit the changes in length to take place freely. The chart in Fig. 23 (*A*) gives the total expansion in a length of 1 ft. as the temperature increases from 70° F. It may be noted by a moment's observation that the rate of expansion increases as the temperature increases.

Having thus seen that expansion and contraction do amount to something, we next pass on to another phase of the subject that is of more immediate interest to engineers and welders. In Fig. 23 (*B*) is shown a bar of steel 1 in. long. Suppose the temperature of the steel to increase 150° F. The length of the bar will increase $150 \times 0.0000067 = 0.0010$ of an inch. The dotted line indicates the expansion. While the bar is still at the increased temperature, as in Fig. 23 (*C*), let us put it in a testing machine and compress it to its original length. Recalling the fact that it requires a unit stress equal to the yield point of the steel to produce a change in length of 0.001 in. per inch, we see that to compress the bar 0.001 in. we would have to apply a force of sufficient amount to produce a unit stress equal to the yield point, or around 28,000 to 30,000 psi. Had the ends of the bar been held originally so that the linear expansion could not take place, the bar would have pushed outward with a force equal to that which would be required to compress it back from its otherwise expanded length.

The reverse of the sequence of events with rising temperature occurs when the temperature of the steel decreases. A corresponding shortening of the bar takes place and, when the bar is so restrained at its ends that contraction is prevented, we have tension stresses developed that may reach the yield point of the steel. This condition arises in welding, only to a greater degree, where the parts are not free to move when the hot weld metal and adjacent base metal cool from the high temperature down to that of the atmosphere.

We see that the tendency to change dimension produced by changes in temperature may set up powerful forces if the dimensional change is opposed. As a familiar example, water reaches its maximum contraction just a few degrees above freezing and begins to expand again as the temperature continues to drop and the water solidifies into ice. Many a waterpipe has burst on a cold winter night because of this fact

The physical properties of steel at elevated temperatures are of importance when we come to consider the matter of shrinkage and the stresses caused by it. In Fig. 24 we have a chart showing the ultimate tensile strength, yield point, elastic limit and elongation for steel at temperatures between 100° and 1300° F. An examination of the curve for ultimate strength shows that it reaches a maximum value at 600° F. and then falls off rapidly to around 14,000 psi. at 1300° F. At 1600° F. the steel loses practically all of its strength.

Steel behaves much as the familiar taffy candy with which many may have had some pleasant experiences in their younger days. When taken off the stove it was liquid (the same as molten steel), but as it cooled it became plastic, at which stage we started to "pull" it. At first, it was fairly easy to stretch but with further cooling the candy became stiffer, acquired more strength or resistance to the pull or stress until finally it became hard and so strong that we could no longer stretch it appreciably. At certain temperatures steel has mechanical properties resembling lead at ordinary temperature.

We are also interested in the ability of steel to transmit heat. Everyday experience tells us that heat is transferred more readily through some substances than through others. You can continue to hold a stick of wood in a gas flame until the wood burns down close to your fingers, but repeat the experiment with a steel rod and it won't be long until the rod becomes too hot to hold. In scientific terms, steel is a better conductor of heat than wood. Silver and copper are even better than steel, but steel stands high on the list. Still air, for example, is a poor conductor and only as we blow air over any object to be cooled can we accelerate the process. In passing, it may be remembered that specifications often require

objects to be cooled in still air in order that the rate of cooling may be slow.

The art of welding owes a great debt to the metallurgists who have brought their training and knowledge to the study of the metallurgical reactions of welding. It is to the metallurgists that we have to look for information about the internal constitution of steel and the alterations in that constitution with changes in temperature. It requires a microscope, often of high magnification, to reveal the changes. To the uninitiated, the microphotographs that we so often see in the literature of welding may seem meaningless, but they are one of the fundamental means of unlocking the knowledge of what has happened to the steel in cooling. From the metallurgists we have learned about the behavior of steel at high temperatures and the sequence of events and changes when the temperature is decreased at various rates.

The scope of this paper is not intended to include any lengthy discussion of metallurgy, but it is essential that engineers and welders have some knowledge of the fundamental elements of the subject. The author recommends highly the paper by Dr. Robert H. Aborn, entitled "Metallurgical Changes at Welded Joints and the Weldability of Steels," The WELDING JOURNAL, October 1940.

Metallurgists have found that steel of structural grade has several different states, depending upon its temperature at any moment or the heat cycles through which it has passed. When this steel is heated to about 1500° F. or above, it is composed of grains of a single constituent having a crystalline structure to which the name "austenite" is given. As the steel cools slowly from this temperature the austenite transforms to a dual constitution, iron and iron carbide, called pearlite (so named because of its mother-of-pearl appearance under certain conditions), which is the crystalline structure in structural steel developed in cooling from the rolling temperature. The rate of cooling may be increased to a definite point and still have all of the austenite changed to pearlite. The increased rate of cooling will be accompanied by an increase in the hardness of the steel and a finer layered structure in the pearlite.

However, when the rate of cooling is greatly increased, there is not sufficient time for the transformation to pearlite to be completed and another hard crystalline structure may begin to form at temperatures below 500° F. that is known as martensite. With still more rapid cooling, we may have no pearlite at all but mostly martensite, which is seriously lacking in ductility and is an undesirable constituent in a welded joint. With increase in the carbon content of steel, a slower rate of cooling is required if martensite is not to be formed. The formation of a martensite structure in tool steel, on the other hand, is very desirable where we want the hardness for cutting metals. This is accomplished by quenching the high-carbon tool steel to accelerate the cooling.

With this very brief and sketchy review of the effects of temperature upon steel, we come to the matter of welding. It is evident that we are dealing with molten metal, high temperatures that are rapidly reduced, shrinkage with its accompanying stresses—in fact, the steel runs the whole gamut of the conditions we have been discussing, any one of which, if nor properly handled, may affect the quality of the weld unduly.

It was stated in an earlier part of this paper that the primary function of welding is to hold the various parts of a structure together. In order to perform this function successfully, the welded joint must come out of the welding operation in such a state of internal structure and with its internal stresses so adjusted that failure will not occur during or after erection or during the life of the welded structure.

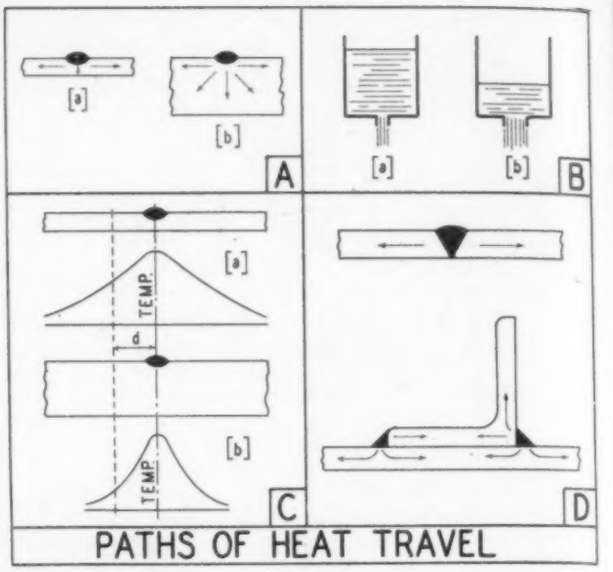


Fig. 25

Let us first take up the cooling of a weld as it affects the structure of the metal. We have seen that the rate of cooling is the controlling factor. In Fig. 25 (*A*) are represented a thin and a thick plate of steel. We shall assume that with the same welding current a longitudinal bead is placed on each plate. When we trace the paths in the thin plate by which the heat can escape from the weld, we find that there are two paths, to the left and right, and a short downward path provided by the steel itself, but escape at the surfaces is retarded by the air which is a poor conductor. On the other hand, the thick plate provides a wider path to the left and right and a longer downward path. The heat can thus escape more readily from the weld on the thick plate, which is another way of saying that cooling can take place more rapidly in thick parts.

Perhaps Fig. 25 (*B*) will illustrate the condition. Let (*a*) and (*b*) be two containers with a small and a large hole, respectively, in the bottom. If we suddenly pour the same quantity of water into each, the time to empty (*a*) will be longer than for (*b*), for the reason that the avenue of escape is more limited or restricted.

This effect of welding on thin and thick material is readily apparent, but if the engineer or metallurgist is going to make any real study of the problem he endeavors to secure some measurements of temperature. One such set of measurements might consist of taking simultaneous readings of the temperature of the steel at different distances from the weld. Figure 25 (*C*) depicts the general form of plots of the temperatures for the two plates of Fig. 25 (*A*). Suppose we select some point at a distance *d* from the weld. We find that in the thin plate the temperature is still quite high, while it is much lower in the thick plate. In other words, the steel will keep hot longer in the thin plate. Referring to the curves again, we say that the temperature gradient for the thick plate is steep, while the gradient is more gradual for the thin plate. One writer likened the two types of charts to pictures of hills—when, of course, the gradient, or slope, assumes a more familiar form.

From what we have discussed about the formation of martensite or even of a hard steel, we can realize that the weld and adjacent base metal of the thick plate may cool so rapidly that insufficient time is provided for the complete transformation of austenite into the softer and more ductile pearlite. The point of most rapid chilling is

along the junction plane of the weld and base metal. Here the weld comes in contact with the relatively cold plate and this is often the region in which failure takes place, either in tests or occasionally in service, if the proper procedure is not carried out.

Welds in structures are of two general types—butt welds and fillet welds. The paths of heat escape for these two types are shown in Fig. 25 (*D*). What has been said about thickness of material applies in all cases and we note that fillet welds are provided with several paths for cooling. In order to reduce the cooling rate it is common practice to use higher currents in welding as the thickness of material becomes greater. Fortunately, for structural welding, the regular grade of steel has such a low-carbon content that the rate of cooling is not so critical, in most instances, as to be serious. It cannot be neglected, however. Based upon practical experience, both the Building Code and the Bridge Code of the AMERICAN WELDING SOCIETY contain a standard of fillet weld sizes in relation to the thickness of material to be welded. The table and chart for their requirements are given in Fig. 26. It should be said that these sizes allow for having a weld of sufficient strength not to crack in shrinking. More about that subject will follow presently.

It is common knowledge that many welds, because of their size, are made with two or more passes. Before considering the effects of multiple pass welding, it will be helpful to discuss the subject of shrinkage and its resulting internal stresses. In approaching this particular topic, the writer recalls a story of his student days when we were studying Applied Mechanics under Professor Gaetano Lanza, whose voluminous book on the subject was our text. It was said that the Lord and "Getty" wrote the book together until they got to the part dealing with the theory of elasticity, when the Lord gave up and dropped out. In dealing with this problem of shrinkage, the author feels that perhaps he, too, should drop out because the best minds among engineers, metallurgists and welding experts have grappled with it and, apparently, still have much to learn.

Shrinkage makes itself evident in the distortions of welded construction with which everyone is all too familiar. Figure 27 illustrates the distortions that occur in a few simple joints when the base metal parts are free to move. If, as in Fig. 27 (*A*), a weld bead is placed on the upper surface of a plate, the plate will be curved upward at the ends. The explanation is simple. We have the once hot weld metal and the adjacent base metal that have cooled and in so doing have contracted, and by that contraction have been stressed in tension, due to the rigid resistance of the cooler portions of the plate. Since this tension is on one surface of the plate, the tension shortens this surface, thus producing a curvature as shown. If we now turn the plate over and run a bead on the opposite surface, the second weld, upon cooling, will exert a pull that will tend to straighten the plate back to its original shape. If applied simultaneously, warpage is avoided and the forces of contraction will be balanced about the center line of the plate. This symmetry of welding is one of the early methods that was employed to minimize distortion in welded construction and is still a good one.

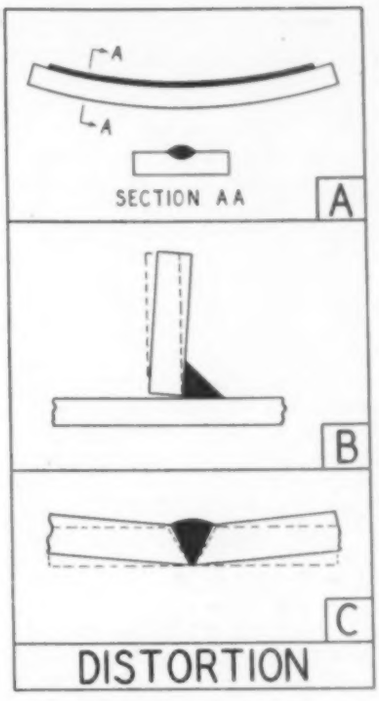


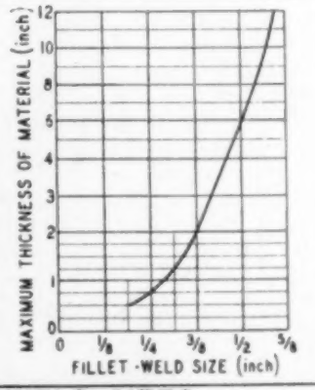
Fig. 27

Next, let us consider the fillet weld of Fig. 27 (*B*). With freedom of movement, the vertical member will be pulled over by the shrinkage of the weld. Supposing that we apply a force to straighten the member we see that we shall have to stretch the face of the weld by an appreciable amount. From what we have observed about the unit stresses set up by contraction and expansion, it is clear that we shall stress the weld metal beyond the yield point, for we cannot straighten a metal part cold without producing stress above the yield point. The placing of a weld on the other side of the vertical member will exert the force to straighten up the vertical member, but in so doing, both welds will be highly stressed.

In the Vee weld of Fig. 27 (*C*), it will be observed that there is a greater extent of hot weld metal at the open face of the joint which is bound to create a greater shrinkage on this face than on the opposite face. Consequently, if the members are free to move, the joint will distort from its original position, shown by the dotted lines. When the joint is rigidly held, the shrinkage causes stresses in the weld metal that may be quite high—particularly on the open face. In a double-Vee joint, we can balance the shrinkage on opposite sides and so avoid distortion, but we may still have high stresses.

As one studies the problem of shrinkage stresses, there seems little doubt but what they are high, generally exceeding the initial yield point. Practical experience has definitely shown, however, that in most cases, when welding on steel of structural grade, these stresses are not serious, for the reason that brittle internal structures are not formed in steel of structural grade if the cooling rate

FILLET WELD SIZE inch	MAXIMUM THICKNESS OF MATERIAL inch
3/16	1/2
1/4	3/4
5/16	1 1/4
3/8	2
1/2	6
5/8	Over 6



FILLET WELD SIZES

Fig. 26

is not too sudden. With pearlite structures, the steel is soft and ductile, the yield point of the steel is well below the ultimate strength and, if a high contraction of force threatens, the metal is able to stretch and prevent high stresses. Whereas, with a hard and brittle structure, as produced by very rapid cooling, the yield point of the steel is very near or at the ultimate strength and, in consequence, any stress beyond the yield point causes rupture. Therefore, what we must bear in mind in all structural welding is to set up conditions such that the weld metal and the heated metal near the weld can cool slowly enough to produce a cold metal having a yield point well below the ultimate strength, or, in other words, we want a pearlitic steel.

When the carbon content of the steel goes above 0.25 to 0.35% we are dealing with steels that need still more time for the development of pearlite and are likely to cool too rapidly through the metallurgical transformations and so possibly develop even the hard martensite. Small tack welds, or even small fillet welds, may be so small that the quenching effect of the cold base metal is so rapid that a brittle structure or even martensite may be formed and there is always the possibility in such cases that the martensite may develop interior cracks which no amount of subsequent heat treatment will correct. Such cracks then become potential sources of later full-sized cracks in the weld itself. Numerous instances of such failures can be traced to the original tack welds that were not thoroughly incorporated by fusion into the final welds or were not chipped out prior to placing the final welds.

We have seen that a too rapid rate of cooling can lead to conditions that may produce cracks in welds. The obvious remedy is to slow down the cooling rate and this is accomplished in two ways. The first can be done in the welding operation by supplying more heat to the joint so that there is more to be dissipated, resulting in slower cooling. Either an increase in the welding current or a decreased speed of welding, or both, will create the additional heat. Many times this method is inadequate and then the steel itself is preheated, which simply supplements the heat of welding and reduces the rate of cooling. In technical terms, we are providing a gradual heat gradient which is favorable to satisfactory metallurgical transformations and internal stress adjustments.

This is, perhaps, a good point at which to discuss briefly the subject of multiple bead welding. Let us assume that the first bead has been placed and, of course, has encountered all the conditions we have been considering. When the second bead is added, the first one is reheated, portions of it remelted and its temperature will be high enough for the metal to lose much of its strength, temporarily. The internal stresses will be relieved since the strength of the metal or the resistance will have been reduced. The heat of the first weld (provided it has not cooled to room temperature) will act as a preheat and, with the heat of the second weld added, we have a slower rate of cooling. Also, metal that has not been heated to a high degree is tempered by the welding heat which will often soften adjacent layers and this is largely the means that produces fine-grained, ductile multi-bead welds.

It has been found that the fewer passes there are, the less will be the over-all distortion though not of stress. This can be explained by the fact that the shrinkage after each pass exerts another distorting force on the joint and builds up an accumulation of distortions. Experience has shown that too much heat results in excessive warping. So we find somewhat of a conflict of effects. It is a case of too little or too much heat being objectionable. No one has yet been able to lay down any exact rules to govern the great variety of conditions that may be encountered. When trouble arises, it is generally possible to analyze the problem and to discover the cause, on the basis of our present knowledge. But it is a much more difficult feat to always anticipate trouble and be able to avoid it. It is easy to travel in your automobile with road maps to guide you, but quite another problem to go directly to your destination over unmapped highways with no guide posts.

In this matter of shrinkage and shrinkage stresses we have to lean heavily on experience. Much has already been learned and reduced to welding procedures that are like road maps to guide us toward our goal of satisfactory results. There are still frontier regions to be explored and procedures to be developed for the new problems as they arise. This method of approach offers the best solutions and we always have the support of past experience, acting as a compass to guide us.

There are times when we wish to have stress-free joints in our structures before they go into service. Structures subject to dynamic shock or fatigue (a subject to be discussed presently) come within this classification. Pressure vessels and some kinds of machinery are examples. One method of achieving this result is by peening the weld. We have seen that when a weld shrinks there are internal tension stresses set up. By hammering the weld in the peening operation we elongate the weld metal just as we enlarge a penny when we hammer it on an anvil. Elongating the weld metal locally relieves the internal stresses which were tending to stretch it. There is always the possibility that we may overdo the peening and set up new stresses by compressing the metal too much.

A much more certain method of stress relief is that of heating the welded construction in an annealing furnace to a temperature of 1100–1200° F. and subsequently cooling it slowly, either in the furnace or in still air. We have seen what happens at this temperature. The internal stresses are almost entirely relieved, since this temperature is high enough to reduce the strength of the base metal and weld metal to a point where the resistance to the internal stresses is greatly lowered. The heat is also sufficient to transform any martensite to a softer and more ductile microscopic aggregate in the steel, and the slow cooling after heating gives ample time for the equalization of stress fostered by any inequalities of cooling.

Of course, we cannot apply the method of stress-relieving to structures such as buildings and bridges; therefore, we must devise proper procedure of design and welding so as to minimize residual stress or at least to keep it within safe limits.

Fatigue Stresses

When we have to deal with structures that carry repeating loads we encounter some new effects that do not arise in structures supporting static loads. We have learned that steel (and other materials, as well) is not able to carry as much stress under repeated loads as under steady loads and engineers, therefore, speak of its fatigue strength. It is as if steel tires when the load is applied over and over, just as we find it increasingly difficult to continue lifting a weight from the floor. We may tire with 25 or 30 lifts, where the repetition for steel runs into hundred thousands or millions.

Around a busy railroad terminal it is easily possible for 200 trains to pass over a given bridge in a day. In a year's time there would be 365 × 200, or 73,000 trains. Assuming a life for the bridge of 50 yr., we have the grand total of 3,650,000 trains over the bridge and each time a train passes over, it causes the stresses to repeat, often several times during the one passage. Clearly, it is a

very practical problem for engineers to determine the fatigue strength of steel, even after millions of repetitions of loading, so that they may design safe structures.

It would occur at once to anyone that welded structures should be considered for fatigue where the loads vary or are repeated. Until recently, there has not been very much study given to this subject. However, its importance has been appreciated and extensive tests are now under way at the Engineering Experiment Station of the University of Illinois. These tests* are under the supervision of the Engineering Foundation and are sponsored by the AMERICAN WELDING SOCIETY and the American Institute of Electrical Engineers.

The method of conducting these tests and a summary of the results obtained to date may be of interest. The specimens have been made up of $^7/_8$-in. thick bars, butt welded as shown in Fig. 28. The fundamental actions of the testing machine are brought out in the sketch. With the machine in the indicated position, let us assume that no load exists on the specimen. As the eccentric at *D* begins to rotate, the connecting rod pushes upward at point *A* on the horizontal lever, causing a downward thrust at point *C*. This thrust produces compression in the specimen which builds up to a maximum with a quarter turn of the eccentric and returns to zero at the

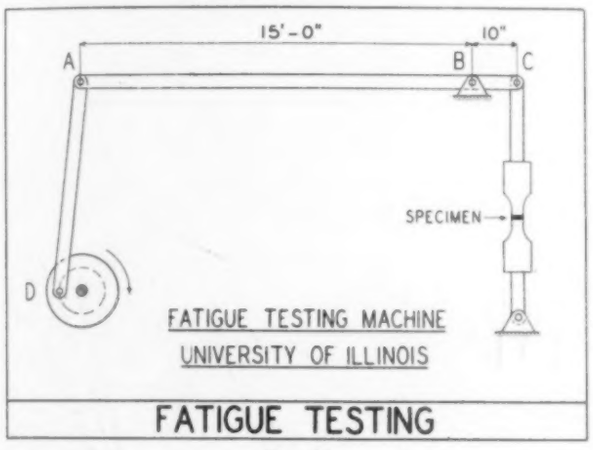


Fig. 28

half turn. For the next half turn, the connecting rod pulls downward at *A*, producing an uplift at *C* and a resultant tension in the specimen. For one turn of the eccentric we have a cycle of stress variation from compression to an equal tension, commonly referred to as a stress reversal.

Instead of starting the stress cycle with the connecting rod in the position shown, let us assume that it is connected to the eccentric at the top. We then have the rod beginning to pull downward on point *A* as soon as rotation starts, producing tension in the specimen and this tension exists throughout the entire cycle with a maximum value for a one-half turn of the eccentric. This condition gives us a cycle of stress from zero to a maximum tension. Again, we might start with the connecting rod at the top of the eccentric, but, by means of a turnbuckle we could pull downward on point *A*, producing an initial tension in the specimen. The resulting cycle produces tension stresses varying from some predetermined value to a maximum value. Of course, there are many different ranges of stress that could be readily brought about, but we shall confine ourselves to the three that have been used at the University of Illinois.

Figure 29 is a diagram of these three cycles which are:

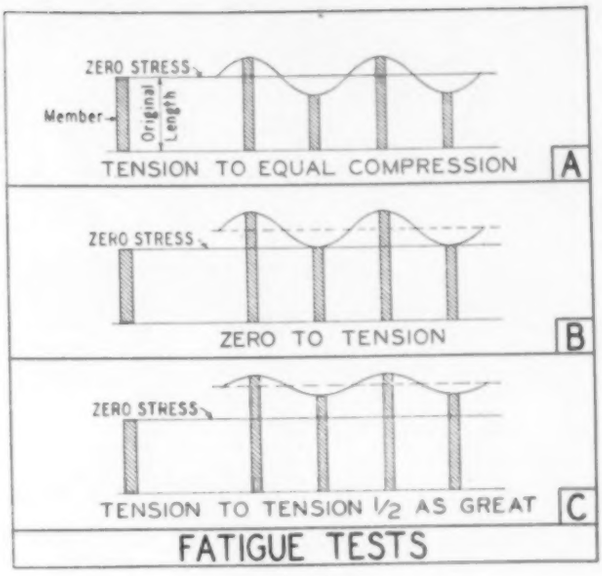


Fig. 29

1. Tension to an equal compression.
2. Zero to tension.
3. Tension to tension $^1/_2$ as great.

A summary of the results so far obtained is tabulated in Fig. 30. An examination of the fatigue strength for a cycle of tension to equal compression and for 100,000 cycles shows that the plain plate, with mill scale on, has a strength of 27,700 psi. This same plate had a tensile strength of 61,300 psi. under a single steady pull. The reduction in strength under repeated loads is clearly evident. When the welded joint was tested in the as-welded condition, a still further reduction in strength was found. From what we have already seen about stress travel we might suspect that the reinforcement brought about some stress concentrations. To determine the truth of such a surmise, other specimens were tested on which the weld reinforcement was either machined or ground off. The fatigue strength was found to be restored to practically the same as that of the plain plate. This same relationship held for the other two ranges of stress cycles. Evidently, then, the notch effect of the more or less angular edge of the weld had a considerable adverse influence upon the fatigue strength of the weld.

When we make comparison horizontally in the table we find that full reversal from tension to an equal compression is the most severe stress cycle, since the fatigue strength is the least. The cycle of zero to tension is much

DESCRIPTION OF SPECIMEN	FATIGUE STRENGTH IN 1000'S OF LB. PER SQ. IN.					
	TENSION TO AN EQUAL COMPRESSION		0 TO TENSION		TENSION TO TENSION ½ AS GREAT	
	N = 100 000	N = 2 000 000	N = 100 000	N = 2 000 000	N = 100 000	N = 2 000 000
As Welded	22.3	14.4	33.1	22.5	53.3	36.9
Reinforcement Machined Off	28.9		48.8	26.4		43.7
Reinforcement Ground Off	26.6		44.5	26.3		
Plain Plate Mill Scale On	27.7	17.1	49.8	31.6		50.0
Plain Plate Mill Scale Machined Surface Polished			59.6			
PLATES - $^7/_8$" thick N = Number of Cycles	STEEL - Carbon Structural Grade Y.P. = 34 800 T.S. = 61 300				Welded Specimens Not Stress Relieved	

FATIGUE TESTS OF BUTT WELDS

Fig. 30

* *Bulletin No. 327* by Wilson, Bruckner, Coombe and Wilde, Engineering Experiment Station, University of Illinois, Urbana, Ill.

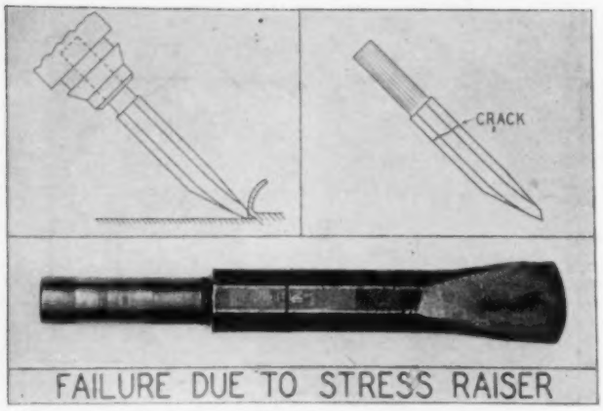


Fig. 31

less severe and the tension to tension $^1/_2$ as great still less so.

How does all this apply practically? If you were designing a welded splice in a tension member of a roof truss or a floor truss in a building, you would have first the steady, unvarying stress due to the dead load. As the live load changed from time to time, additional tension would be induced in the member, resulting in a condition approaching the third cycle in the table of Fig. 30. We see that, even for 2,000,000 cycles, the fatigue strength is greater than the yield point and since designs are based upon the yield point it is, therefore, not necessary to consider fatigue stresses. This is quite generally true of building construction, except perhaps where cranes or other moving loads are supported by the structure.

In bridges, it is possible to have members known as hangers which may have a comparatively low dead load stress, but a high live load stress—a condition similar to the second cycle and there we see that for 2,000,000 cycles the fatigue strength is lower than the yield point. Here is an obvious case in which the engineer must take account of fatigue and use lower working unit stresses.

Full reversal of stresses is less common in structures, although it occurs regularly in many reciprocating parts of machines. When such conditions are encountered, the engineer must make an allowance in his calculations for the decreased fatigue strength.

The Specifications for Welded Highway and Railway Bridges, published by the AMERICAN WELDING SOCIETY, give great prominence to this matter of fatigue and anyone will be repaid by studying them. Without going into the detail calculations of the design let us ascertain the weld area required in the butt-weld connection of a member in which the stress varies from 60,000-lb. tension to 60,000-lb. compression. At no time will the stress exceed 60,000 lb. and were it always one or the other kind of stress, the calculation of the weld area would call for 4.45 sq. in. Since the stress condition is one of full reversal, the specifications require 6.67 sq. in. We see that engineers recognize and take account of the decreased strength under fatigue conditions.

Figure 31 is an actual case of fatigue failure of some chipping chisels in service. While it is somewhat out of the field of structures, it brings out clearly some of the points discussed earlier in this paper. A series of failures of these chisels was brought to the writer's attention and the cause of failure was readily apparent. The upper left-hand sketch illustrates the working position of the chisel and a moment's thought will show that there is a bending action that produces tension on the under face of the shank. The crack occurred as shown in the upper right-hand sketch. The photograph of the under face of the chisel reveals the cause. The trade name of the maker was cut with a steel stencil and it will be noted that the crack passed through the first indentation that lay across the line of stress. We saw earlier that a sharp notch caused a stress concentration and this concentration, combined with the repeated stressing of the chisel in service, caused the final fatigue failure. When the practice of stenciling the chisel was changed the trouble stopped.

Still another type of fatigue failure is illustrated in Fig. 32. Perhaps you have split an apple in two by taking it in both hands and twisting it. You did not pull it apart in tension, but what you did, in the language of the engineer, was to subject it to a torsional shear that was great enough to produce failure. When we were discussing beams, we saw that there was a shearing action tending to slide one portion of a beam past the other. Now torsional shear tends to slide one part past another.

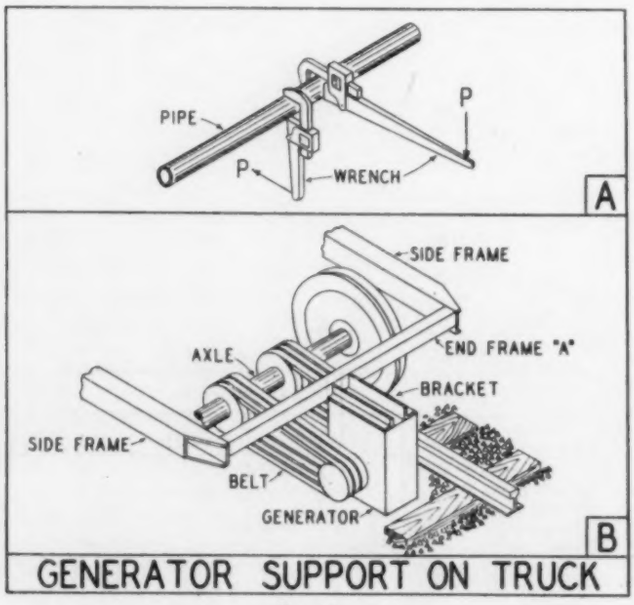


Fig. 32

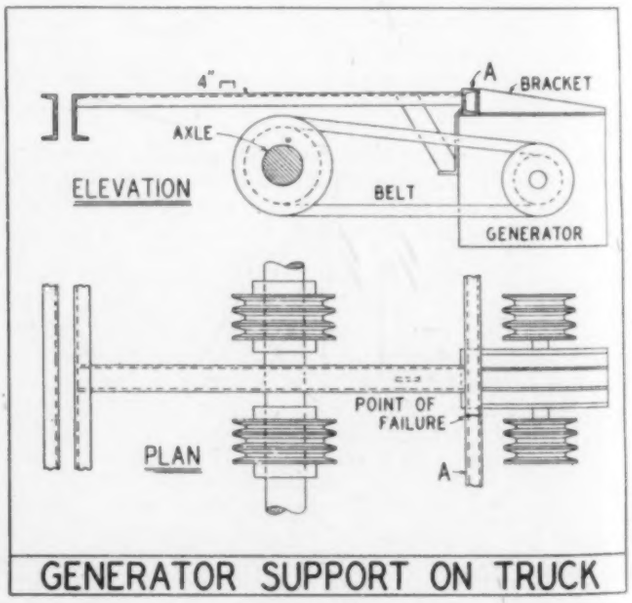


Fig. 33

but does it by twisting rather than a straight sliding action. When, as in the illustration, you put a Stillson wrench on a pipe and apply pressure to the handle, you twist the pipe and cause torsional shearing stresses in it.

A round member, whether solid or hollow, is best suited to carry torsional shear because the stress has a smooth path for its flow. That is why shafts, axles, etc., are almost invariably round, although their machining is also an important reason. When, however, we have a rectangular member carrying torsion we run into stress concentrations at the corners, just as we do when notches occur in the path of direct stresses.

This sketch shows a cross member of a passenger car truck which failed. It supported the electric generator that was driven by a Vee belt from the axle. The end frame member, marked *A*, was a small channel with a plate welded between its toes to form a box section. A bracket welded to the boxed channel was the support for the generator, and, as we saw in the case of the cantilever beam, the moment caused by the load had to be resisted by the support. It will be seen that the pull of the belt caused still more twisting moment. You might think of the bracket as a Stillson wrench with the weight of the generator as the force applied to the handle. The pull of the belt is as if a rope were attached to the handle of a second wrench and thereby applying an extra twist. In this case, the boxed channel was the pipe and it had to carry the twist to the two side frames of the truck. So we have a case of torsional shear and combined with it was the continual vibration, or bouncing, that unquestionably caused the stress to alternately increase and decrease.

Figure 33 is an elevation and plan view of this generator support. The point of failure in the end frame *A* is indicated on the plan view.

Figure 34 (*A*) shows the ideal circular section for resisting torsion and also a rectangular section with a rounded fillet at *A* and a square corner at *B*. As the torsional shear travels around the member it behaves in a similar manner to stress traveling in a straight member. A large, smooth fillet facilitates the flow, but a sharp corner causes the inevitable crowding and stress concentration, with the possibility of failure, particularly in fatigue when, as we have just seen, the ultimate strength is reduced.

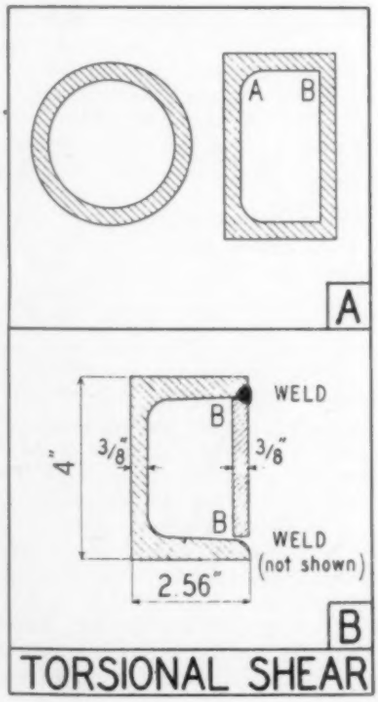


Fig. 34

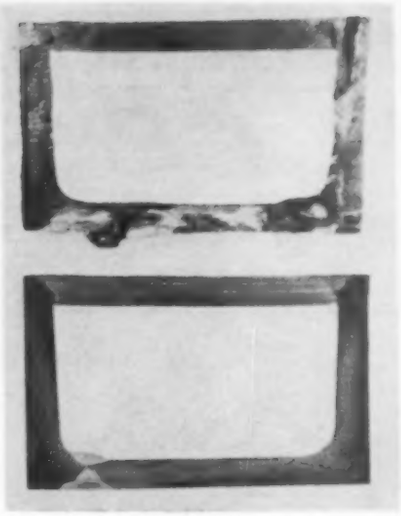


Fig. 35

Figure 34 (*B*) is a cross section of the box channel and, as you might easily suspect, the welds did not attain full penetration. So there was a sharp angular notch that provided a very high-stress raiser. Fatigue failure was inevitable and actually took place. The photograph of the failure in Fig. 35 clearly shows the incomplete penetration of the welds, the sharp notches and the characteristic lines of a fatigue failure. This is another example of a stress-raising condition coupled with fatigue and the result could almost be predicted. Failures of this kind teach valuable lessons and lead to progress in the development of knowledge that enables engineers and welders to profit from experience and to plan their work to avoid future trouble. It is a good illustration of the reason why engineers are always studying and testing so that they may learn the facts which will anticipate trouble and avoid it before an actual structure is built.

Conclusion

The author has refrained from adding to the length of this paper by citing examples of construction to illustrate the topics that have been discussed. Welding literature has a wealth of descriptive material relating to all classes of structures. It is hoped that this paper will enable the reader to obtain added benefit and pleasure from the technical articles in the JOURNAL of the AMERICAN WELDING SOCIETY and other publications. There is a saying that "he who would bring back knowledge must take knowledge with him" and likewise the man who would get something out of his reading must have some knowledge to enable him to understand what he reads.

Throughout this paper, one must have been impressed with the widespread study that has been given to the whole subject of welding. Technical men and practical men have all contributed to the general fund of knowledge. Welding still presents many unsolved problems and offers fine opportunities for research and investigation. Engineers, metallurgists and welders will be instrumental in solving most of the problems.

In bringing this paper to a close there comes to mind the short two-verse poem of J. Mason Knox entitled "Cooperation."

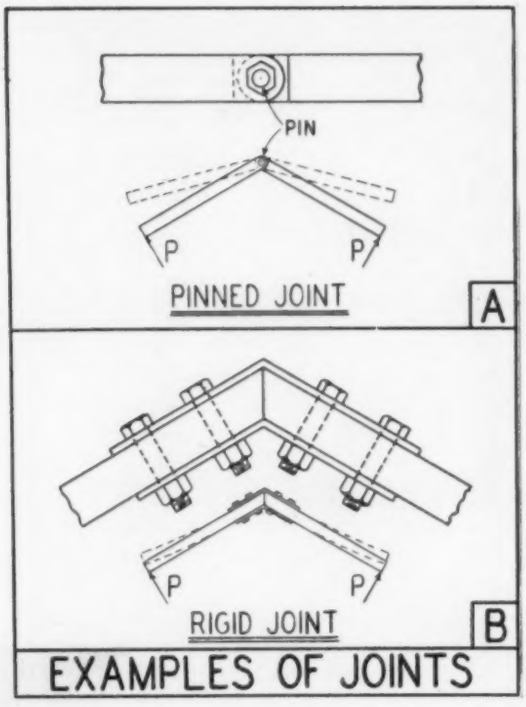


Fig. 36

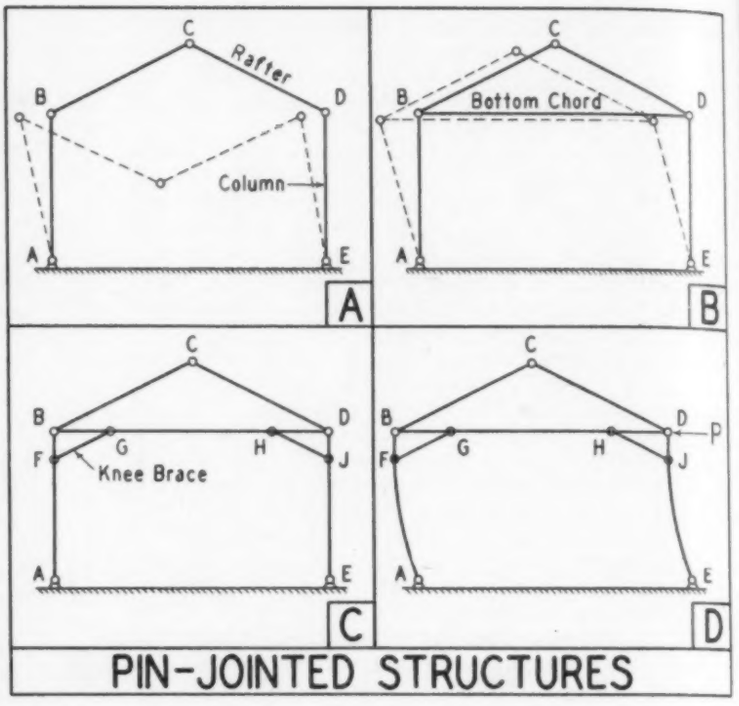


Fig. 37

It ain't the guns nor armament
Nor funds that they can pay,
But the close cooperation,
That makes them win the day.

It ain't the individual
Nor the army as a whole,
But the everlasting teamwork
Of every bloomin' soul.

Appendix*

The joints in structural frames are of two types, as exemplified in Fig. 36. The pinned joint is characterized by its lack of any resistance to bending. When, as in Fig. 36 (*A*), we apply forces *P* to the members, a rotation of the members about the pin takes place. There being no resistance to the forces (neglecting the small friction between the pin and the members) the rotation will continue as long as the forces are applied.

The distinguishing feature of a rigid joint is its resistance to bending action. Such a joint is depicted in the upper sketch of Fig. 36 (*B*). Splice bars are bolted to the members on opposite sides and serve to stiffen the joint against the bending action of the forces *P* in the lower sketch. Instead of rotation occurring, we find the ends of the members being deflected to the dotted position, while the relative positions of the members at the joint remain unchanged. In other words, the angle between the members at the joint remains constant. Rigidity is obtained in various ways in practical construction, but in all cases the angles between the members at a joint maintain the same values under all conditions of bending.

The action of a pin-jointed structure is illustrated in Fig. 37. In Fig. 37 (*A*) is shown a typical mill building bent, consisting of columns and rafters. It is evident that the frame can take any one of innumerable positions—one of which is shown by the dotted lines. It is a general principle of engineering that a pin-connected structure must be built up as a series of triangles if it is to be stable. As a start, let us add the Bottom Chord member *BD* in Fig. 37 (*B*). Now the members of the triangle *BCD* are linked together and are stable with respect to themselves. Still the framing as a whole is unstable because the structure can assume any such position as shown by the dotted lines. It will be noted that the angles between the columns and the bottom chord can change, due to the pin connection of the columns to the triangular frame *BCD*.

The kneebraces, *FG* and *HJ*, in Fig. 37 (*C*) form triangular frames with a column and a portion of the bottom chord and by so doing they create a condition which prevents any angular changes between the upper ends of the columns and the bottom chord. Now we have attained a stable structure and an examination of any existing mill building will reveal the fact that, basically, these principles have been followed. Of course, there will be found many additional truss members that fill in the space between the rafters and the bottom chord but their function is to provide adequate support for the long members.

In such a structure, as shown in Fig. 37 (*C*), it is interesting to observe the action when some lateral force, such as *P*, is applied to the frame, as at Joint *D*. This force might arise from the pressure exerted by the wind blowing against the building. It should be noted that in all such structures the columns and bottom chord are not separate members, pinned together at the joints *F*, *G*, *H* and *J*. The columns are one piece from *A* to *B* and from *E* to *D* and, likewise, the bottom chord is continuous through points *G* and *H*. Only the ends of the kneebraces are considered as having pinned joints. The result of this condition is that the columns and bottom chord are capable of resisting bending moments at the points of connection of the kneebraces. This is particularly true of the column, but in actual practice we use the interior truss members to brace the bottom chord against the bending and so relieve it from the burden of carrying the bending stresses in addition to the direct tensile stress.

When any force *P* is applied transversely to a struc-

* Note: A demonstration of several illustrative models formed a part of the oral presentation of this paper. In response to numerous requests, this appendix has been added so as to include a brief discussion of some of the models.—The Author.

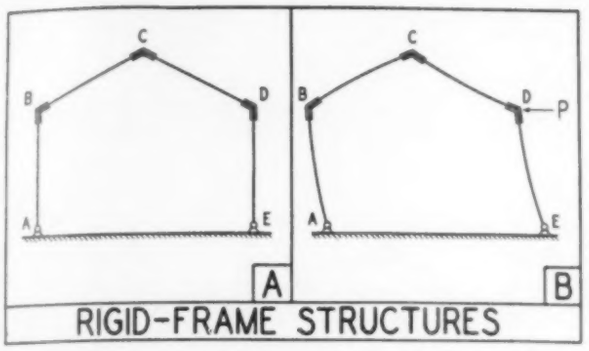


Fig. 38

ture, we know, from the definition of force given in an early part of this paper, that it will produce motion unless it meets resistance. The only place such a frame, as shown in Fig. 37 (*D*), can offer resistance to the force *P* is at the foundations of the columns at points *A* and *E*, where the structure rests on the ground. We know that properly designed buildings do not slide around over the ground whenever the wind blows or the crane exerts a horizontal thrust. Hence there must be horizontal forces acting at *A* and *E* in a direction opposite to that of the force *P*. A glance at the portions of the columns below the kneebrace connections will reveal that they act exactly as the cantilever beam in Fig. 16 (*A*) and are deflected by the horizontal resisting forces in the same manner.

In most structures that one sees today, one would look in vain for actual pins at the joints. The types of connection at the joints resemble rigid construction but it is common practice to consider all such joints as pinned when calculating the direct stresses. This greatly simplifies an engineer's calculations and ordinarily does not lead to any serious errors in the stresses. In important structures, however, the engineer does take the rigidity into account and does calculate the bending stresses, which he ordinarily calls the secondary stresses. Such computations are sometimes long and tedious. Here then are illustrated the fundamental principles that underlie the design of engineering structures.

There is coming into greater use a form of structure known as the rigid frame structure. It depends for its stability entirely upon the resistance to bending that is offered by the joints. Such a structure is depicted in Fig. 38 (*A*), in which the general outline of the building is the same as in Fig. 37 (*C*). When the horizontal force *P* is applied, it causes a sidewise movement of the upper portions of the structure but since the angles between the members at the joints *B*, *C* and *D* cannot change, it is clear that no such action can take place as was possible in Fig. 37 (*B*). Instead we have all the columns and rafters subjected to bending actions and the result is that the members tend to distort as shown in Fig. 38 (*B*). If the reader will lay a straight edge on each member of the sketch, the curvature of the member will be more evident. The sketch has been drawn to an exaggerated scale to show the distortions in the frame.

From this brief exposition of the principles back of the design of pin-jointed and rigid frame structures it will be clear what sort of forces and moments are encountered. When connections between members or parts of members are made with welding, it is equally clear that an engineer must know what forces, moments and stresses are involved so that he can call for the proper amount of welding and provide for its disposition in a manner best suited to transmitting the stresses without undue concentrations.

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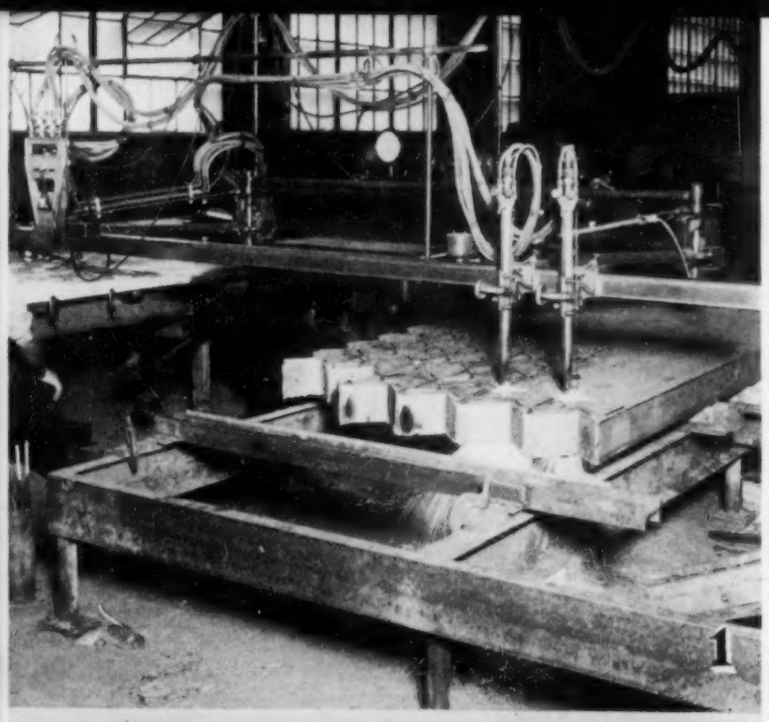

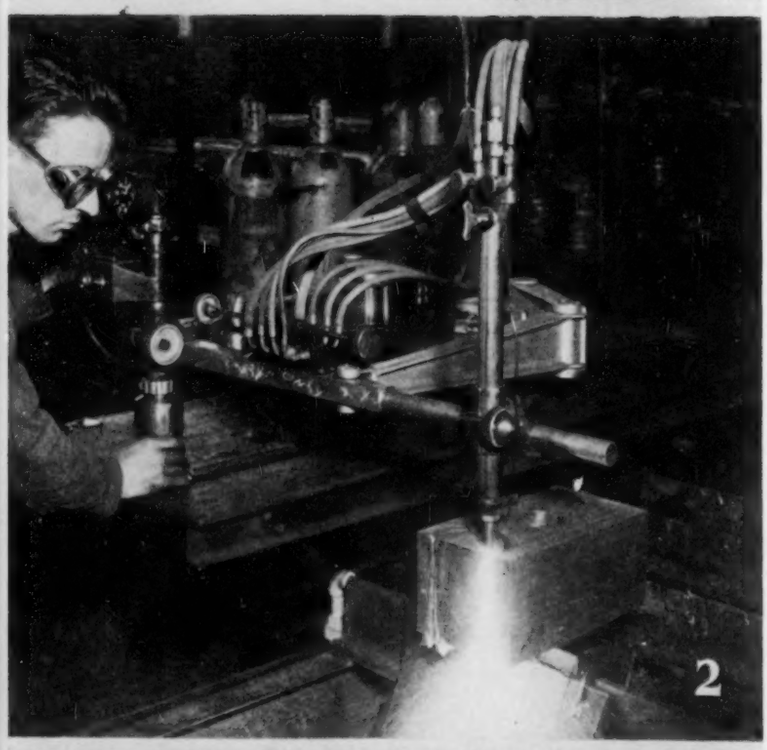

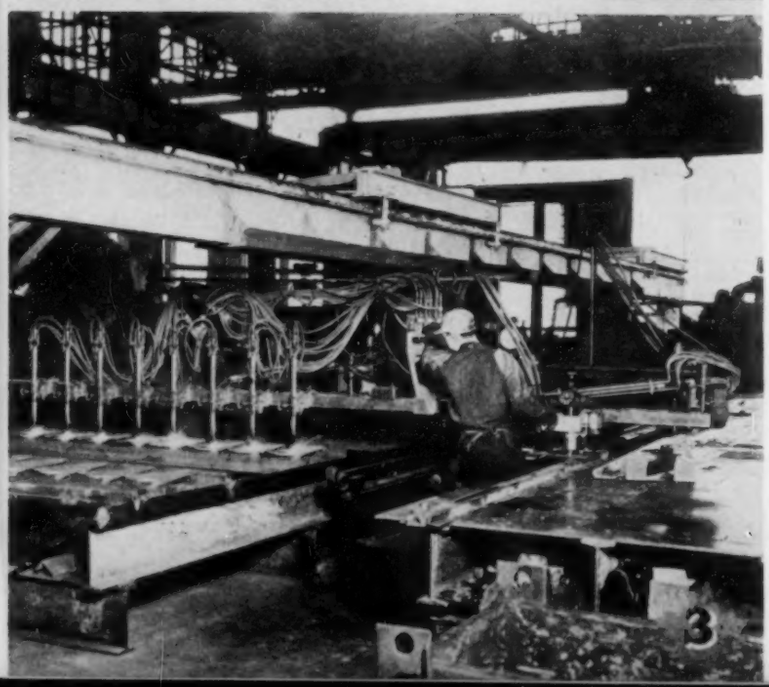

Oxyacetylene Cutting in Production

By R. F. Helmkamp* and A. H.†

THE use of oxygen cutting in fabricating defense materials has answered the demands for a speedy yet flexible procedure for producing shape-cut steel pieces in mass quantities and to eliminate unnecessary machining operations. Under the impetus of the war program, ingenious new applications of flame cutting are meeting the tempo required for victory in this colossal industrial battle. Nor is accuracy being sacrificed in the clamor for speed. Modern industry is equipped with precision machines which carry ten cutting torches over the course laid out by a single template, producing as many as forty identical pieces in a single operation. In other applications, production engineers are using oxyacetylene cutting to replace machine tools for preliminary preparation of blanks and forgings for final machining. The economy inherent in flame cutting is often relegated to lesser consideration in these cases, being far overshadowed by the extraordinary speed advantage which it contributes to expediting production.

One manufacturer engaged in making vital ordnance parts was hampered in fabrication of alloy blocks by a 4-hr. sequence of operations per piece, merely for rough machining. But when oxyacetylene cutting was applied for rough shaping of these blocks, the 4 hr. were reduced to 15 to 20 min. These blocks are of high alloy steel, a difficult steel to cut, but by the commonly accepted practice of preheating arranged for in this instance in a furnace adjacent to the cutting table, and mounting the heated block in a specially constructed water-cooled jig which automatically positions it for accurate machine cutting, as shown in Fig. 2, the flame readily cuts the tough steel at a rate of 5 in. per minute.

Multiple torch cutting enables such rapid production that it becomes essential to provide adequate crane or other handling facilities to avoid idling the cutting equipment while carrying the work to and from the machine. While it is true that multiple torch cutting is economical even with small volumes of work, large volumes are becoming the rule rather than the exception in defense production, and applications of flame cutting which were once considered innovations are now being adapted by plant engineers into accurate mass production practices. Thus valuable time is being saved by using plate stock of the usual "run-of-the-mill" material,

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* Presented at the Annual Meeting, A. W. S., Philadelphia, Pa., Oct. 20 to 24, 1941.

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Fig. 1—A 7-Inch Steel Slab Is Quickly Transformed Into Tractor Brackets by Multiple Torch Flame Cutting. Waste Is Minimized by Nesting the Shapes. The Two Torches Cut Ten Pieces Before Shifting to a New Position

Fig. 2—This Alloy Steel Forging Is Quickly Cut to Shape by the Flame with the Planograph. The Block Is Held in Position by a Water-Cooled Jig While the Magnetic Tracing Device Guides the Torch to the Pattern Laid Out by the Template at Left

Fig. 3—Defense Urgency Is Met by Setting Up Eight Torches on the Travograph Directed by a Four-Shaped Template, Cutting 32 Identical Pieces in Each Pass. Overhead Cranes Facilitate Materials Handling and Cut Down Idle Torch Time

Cutting Speeds War Production*

Welmaker and A. H. Yoch†

and where one or more adjacent faces of a cut are of identical shape the work is laid out to utilize one cut to serve both edges, thereby increasing speed of production and economizing on gases. Even greater speed is achieved by designing a double template, such that the torches may continue without interruption into a second set of multiple cuts, without stopping to shift to a new position. This device is feasible only on simple designs, of course.

An example of efficient application in producing 32 pieces of finished cut plate in one complete circuit of the contour of the template by the magnetic tracer is shown in Fig. 3. In this setup adequate provision for quick handling of materials is made by the special structure with two cranes erected over the travograph machine. As with most other flame cutting operations no jig or fixture is required to hold the stock in place. The template itself is a multiple design, guiding the torches along a circuitous path which produces four complete pieces of the desired shape from each torch.

Tractor sprockets for military tanks are also cut to an accurate contour by the four-torch arrangement illustrated in Fig. 5. The inside openings are cut first; then by shifting only the tracing device on the template, the outside periphery is cut on the four sprockets simultaneously.

One of the more significant reasons for the lopping off of months from the scheduled launching dates of naval and merchant ships has been the mass production contributions of oxyacetylene multiple torch cutting of the many plates and shapes encountered in shipbuilding. Plate layout and materials' handling facilities are designed to service large shape cutting machines of the pantograph type, rather than submitting to the limitations of small portable machines. These are used on supplementary operations for straight-line or circle cutting, and for sundry multiple cutting jobs.

Multiple torch cutting which leaves usable scrap is often deliberately planned to leave more waste between the cut pieces than is necessary, in order to have sufficient remaining space to allow subsequent cutting of smaller multiple shapes from these areas, thereby obtaining the greatest practicable number of finished pieces from the plate stock. An additional advantage may be obtained, moreover, by fixing the two templates in proper position to enable both sets of multiple cuts to be made in succession, without shifting the torches from their relative positions and without moving the work piece.

Fig. 4—The Torch Is Cutting a Small Hole Adjacent to a Large One in This Ship Bulkhead Plate. The Customary Radius Rod Is Utilized, and the Radiograph Rides on a Flame-Cut Supporting Ring Overhanging the Large Hole

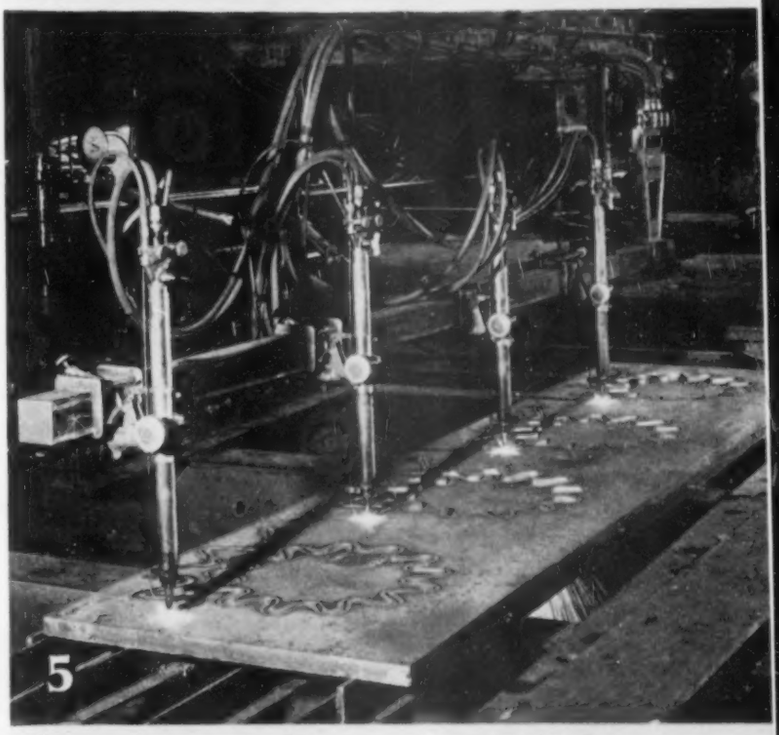


Fig. 5—This Scrap Piece from Which Four Tank Sprockets Have Been Cut Shows the Smoothness of Contour Obtainable on Intricate Shape Cutting. In the Background Four Torches Rapidly Cut Another Set of Sprockets, Cutting Inner and Outer Contours in Successive Operations

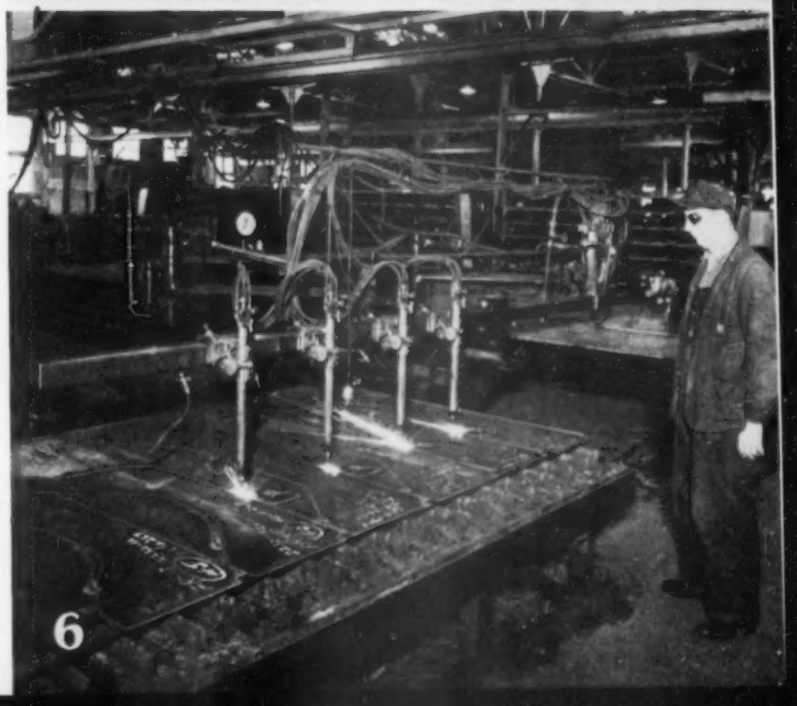


Fig. 6—Another Ingenious Method to Speed War Production Is This Double Multiple Operation with the Travograph, Using Two Different Templates. The Second Set of Four Shapes Is Cut from the Scrap Left Between the First Set

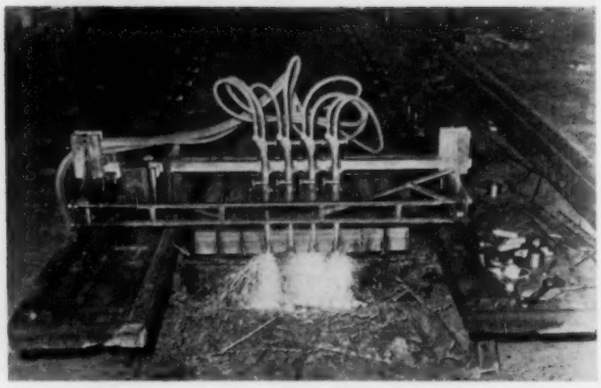


Fig. 7—An Emergency Setup for Splitting Ingot Iron Slabs Into Billets

The Trolley Torch Carrier Rides on Improvised Tracks, Propelled by a Radiagraph, and Defense Needs Are Met Despite the Absence of a Billet Mill.

An application of this practice is illustrated in Fig. 6, where four hull stiffeners have already been cut from the plate, and, without pausing to remove them, the operator is cutting four lever shapes from the scrap. Following this, all eight pieces are removed and the work shifted for another double multiple operation.

The exigencies of defense have brought about demands for oxyacetylene cutting machines as a necessary supplement or substitute for shears and other mechanical cutting equipment. With the conversion of strip mills, equipped with shears limited to gage metal, into plate mills, there has come the emergency development of oxyacetylene apparatus to cut plate and slabs on the mill, at speeds conforming to the rolling schedule. Such apparatus in some cases has been installed because of the extreme difficulty of obtaining the customary mechanical cutters, and has proved to be economical because of reductions in handling of the work.

An outstanding instance where oxyacetylene cutting filled a breach is the recent development of a machine to cut large billets while hot. The steel mill now employing the original machine had been limited by billet shears of 10-in. capacity, while receiving orders for 12- and 16-in. square billets. Cold sawing required more than 2 hr. for the largest sizes, and necessitated the added expense of reheating for rolling. The remotely controlled machine cutting torch severed the 12- by 12-in. billets while at a temperature of 1950° F. in 1 min. 17 sec., thus amply conforming to the billet production rate of one every $2^1/_2$ min. Both the torch and the Radiagraph machine are water-cooled, and the operator controls vertical and horizontal movement from a remote control box acting through relays mounted on the machine.

One example of emergency application of flame cutting is the slab splitting operation shown in Fig. 7. In this instance a slab mill with an order of 4-in. square billets, having no billet mill in the vicinity, decided to flame cut the slabs. Accordingly, they constructed a trolley carriage employing a multiple torch setup, propelled by a Radiagraph. Ten torches are used, traveling the 26-ft. length of the slab for complete splitting into billets, enabling the entire job, including trimming of both edges, to be done in one pass.

The ready adaptability of flame cutting is proving to be the practical solution to many problems occasioned by the emergency, other than in "pinch-hitting" opera-

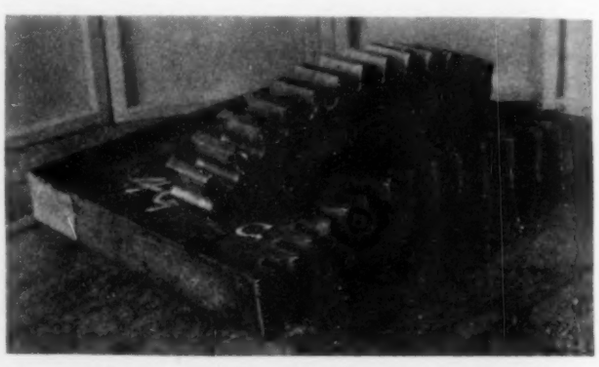


Fig. 8—A Segment of a Flame-Cut Gear Cut from 0.45 Carbon Steel 6 In. Thick

These Segments Were Welded Together Using a Plate Disk or Structural Shapes for Spokes and a Hub to Form a Gear 8 Ft. in Diameter. Flame Cutting Was Sufficiently Smooth and Accurate That Machining of Teeth Was Unnecessary for the Service to Which This Gear Was Put.

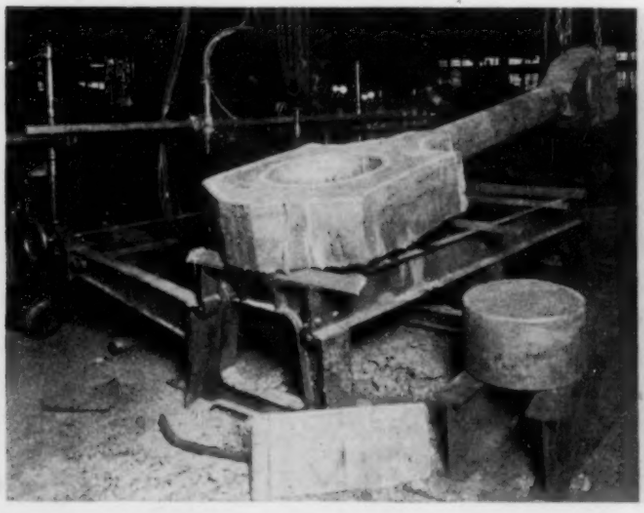


Fig. 9—A Giant Marine Engine Connecting Rod, Flame Cut to Shape Prior to Finish Machining

Note the Smoothness of Cut on This Heavy Work, Shown by the Scrap Piece in Foreground.

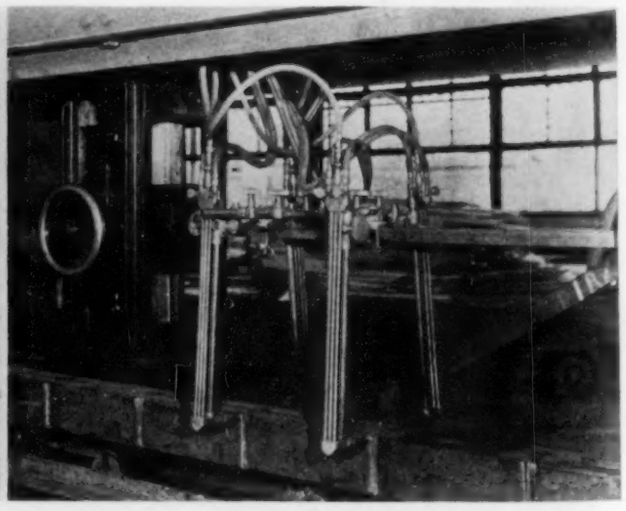


Fig. 10

For High-Speed Nicking of Large Billets This Motorized Device Cuts Two Pairs of Opposite Nicks of Uniform Depth. Billet Then Is Broken Up Into Shell Stock Forging Blanks. Additional Dual Torch Arrangements May Be Accommodated.

tions such as the foregoing. Thus the increasing difficulty of obtaining steel rolled to exact dimensions is being met, particularly in shipyards, by using standard mill shapes and flame cutting them to the exact shape desired. In a number of instances special machines have been designed to fill this need.

This same problem of inability to obtain regular equipment or repair parts promptly, or at all, has stimulated resourceful operating heads to fabricate the needed equipment by oxyacetylene cutting and welding. This practice is being adopted particularly in the railroad industry, to recondition locomotives and rolling stock which normally would be consigned to the scrap heap. Many of these applications of oxyacetylene cutting are such as have not heretofore been considered standard procedures, but are rapidly assuming that character as the methods are worked out in practice.

In a plant now engaged in war production another fabricating operation has been speeded up. The rectangular openings cut in the side of a corrugated heat exchange header were formerly cut singly at a rate of 19 each 8 hr. The same pieces are now being turned out at a rate of 100 to 120 per 8-hr. day by the staggered arrangement of ten torches.

Numerous heavy forgings require cutting to shape prior to finish machining, and past experience in heavy cutting is serving as the basis for preliminary oxyacetylene shaping of such pieces as the connecting rods for reciprocating marine engines, being built in substantial numbers under the shipbuilding program. The finished cutting of a large connecting rod is shown in Fig. 9, with the crank end in the foregound. The outer contour and the crank pin opening have been cut to shape, allowing about $^{3}/_{4}$ in. for finish machining. Smoothness of the cut is revealed by the waste block at right.

Mass production of shell blanks calls for an accurate and fast method of cutting billets to sizes for forging. Experiences gained in the last war, modified by recent advancements, have demonstrated the nick-and-break procedure to be not only the quickest and most economical, but also the only method which produces the required square, natural fracture, facilitating inspection for internal defects.

Fig. 11

This Photo Shows an Efficient Procedure for Complete Cutting of Smaller Billets by Oxyacetylene with the Radiagraph. Two Workmen, One Handling a Preheating Torch Ahead of the Machine Cutting Torch, Are Able to Produce 54 Cut Blanks per Hour.

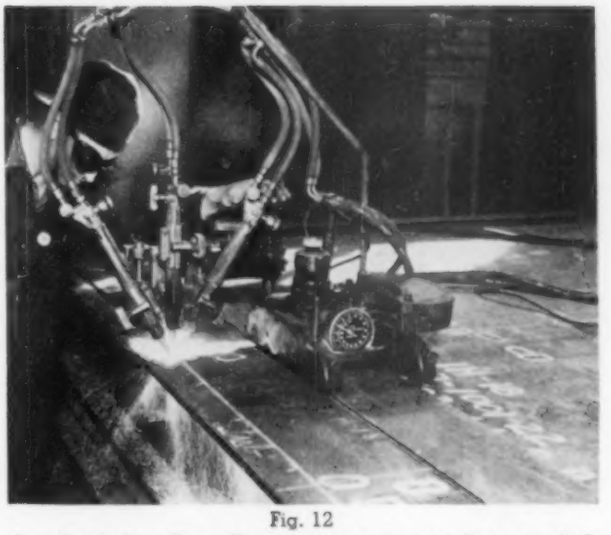


Fig. 12

In a Single Pass Three Torches Mounted on the Radiagraph Cut Two 45° Bevels and a Vertical Land on This Ship Plate Preparatory to Arc Welding.

Billet nicking by oxyacetylene has been adopted by numerous manufacturers of shells and bombs, sometimes using manually operated torches, or specially constructed torch-carrying apparatus with a conveyor to carry the nicked billets directly to the bulldozer. The four-torch setup illustrated in Fig. 10 simultaneously cuts two sets of parallel nicks up the sides of the billet. This does not, of course, represent the ultimate in rapid billet nicking, but the straightness of the billet is a limiting factor in the number of simultaneous nicks which can be made.

It has been found that a comparatively shallow groove is sufficient to produce a sheer, clean break. This applies to both square and round stock. Nor is it necessary to cut a continuous groove all around, because the localized heating normally produces highly stressed areas toward the unheated core, encouraging a sheer break when shock or pressure is applied. This operation has since been arranged to nick one side only using twelve torches nicking simultaneously.

Several different procedures for oxyacetylene nicking are being adapted to modern armament requirements. It is possible, with certain steels, to obtain a sheer break by nicking only one side, and in such cases the nicks may be cut by hand. The operator rolls from one position to the next on a seat straddling a group of billets, guiding his torch along the guide bar attached to the carriage. However, most shell specifications call for an analysis of steel which must be nicked on two opposite faces to secure a clean fracture under the hydraulic press.

Where the billets are of very small size, and inspectional requirements permit, it has been found economical to cut completely through with oxyacetylene. An efficient procedure developed by a Canadian company produces 54 cut blanks per hour, using two operators one of whom handles a preheating torch ahead of the machine cutting torch, the other removing flash, stacking and stamping the cut billets for identification. Figure 11 illustrates this setup.

The vast number of all-welded ships called for by the greatly augmented maritime program has spurred applications of oxyacetylene cutting for plate edge preparation. Double bevels of the same or different angles, with or without vertical land, are speedily cut in a single pass, using two or three torches mounted on a Radiagraph. Figure 12 shows a three-torch apparatus cutting two 45-deg. bevels with a $^{1}/_{16}$-in. vertical land.

Conservation of Welding Electrode

By Clayton B. Herrick*

THE necessity of conserving materials in the war effort is nowhere more urgent than in the use of welding.

Welding is the key process which is making possible production of war ships, military planes, tanks and practically all other war equipment at the tremendous speeds which are vital to this country's speedy and complete victory.

In order that welding may contribute its utmost potentiality in war production, it is important that welding materials be utilized to maximum advantage. This applies particularly to welding electrodes.

The electrode for welding is probably the most essential piece of war industry equipment today. It is the electrode which provides the metal of proper physical properties and operating characteristics permitting production of highest quality welds in minimum time and at minimum cost.

There are a considerable number of factors which affect the most efficient use of electrodes. If conscientiously controlled, these factors will contribute to best use of welding in the war effort. The result will be a still faster rate of production by the use of welding and full utiliza-

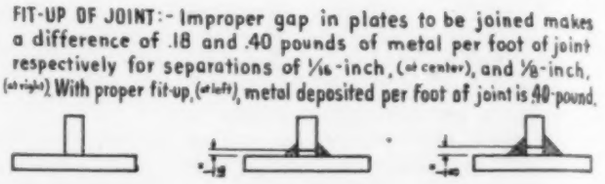
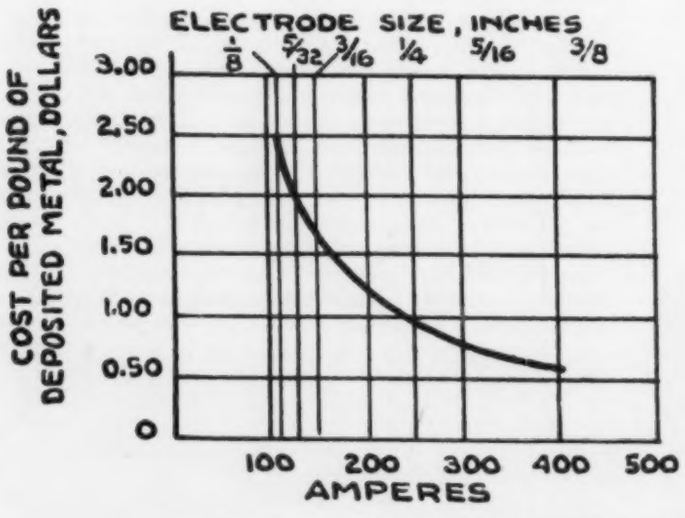

FIT-UP OF JOINT:- Improper gap in plates to be joined makes a difference of .18 and .40 pounds of metal per foot of joint respectively for separations of 1/16-inch, (at center), and 1/8-inch, (at right). With proper fit-up, (at left), metal deposited per foot of joint is .40-pound.

Fig. 1—Variations in Fit-Up of Joints Affect Electrode Consumption to Large Extent

* Welding Engineer, The Lincoln Electric Company, Cleveland, Ohio.



ELECTRODE SIZE:- Effect of electrode size on economy is shown in the chart at left and table below. Note how the cost of welding goes down as electrode size goes up. Note, also, electrode consumption rate, pounds of electrode deposited per hour, number of stub ends, (indicated by interruptions per pound consumed), and cost of interruptions to change electrodes.

Fig. 2—Chart and Table Showing Effect of Electrode Size on Welding Economy

Effect of Changing Electrode Size

Electrode size	1/8	5/32	3/16	1/4	5/16	3/8
Amp.	110	130	150	250	325	425
Arc volts	24	25	26	30	34	38
Kw. at arc	2.64	3.25	3.9	7.5	11.1	16.1
Consumption rate, lb. per hr.	2.6	3.3	3.95	7.5	10.7	16.2
Deposit, lb. per hr. (50% operating factor)	0.87	1.1	1.32	2.5	3.57	5.4
Efficiency of set (%)	47	50	51	55	59	59
Kilowatt input	5.6	6.5	7.65	13.65	18.8	27.3
Interruptions per lb. consumed	18	12	8	5	3	2
Cost per Pound Deposited						
Labor	$1.150	$0.909	$0.758	$0.400	$0.280	$0.185
Overhead	1.150	0.909	0.758	0.400	0.280	0.185
Power	0.064	0.059	0.058	0.055	0.053	0.051
Electrode	0.150	0.135	0.127	0.127	0.127	0.127
Cost of interruption (including overhead)	0.050	0.033	0.022	0.014	0.008	0.005
	$2.564	$2.045	$1.723	$0.996	$0.748	$0.553

CONSERVATION OF WELDING ELECTRODE

TYPE OF JOINT: - Proper joint to select is the one which meets service requirements and costs the least. Obviously, if requirements are met by the simpler type of joint, which requires less machining and less electrode, it is a waste of time, labor and materials to use a more complicated type.

BUTT JOINTS

1. PLAIN BUTT JOINT. Largely used on plates up to ⅜" thick with metal electrode ¼" with carbon electrode, although generally used below this. Inexpensive as to preparation of joint. Suitable for all usual load conditions if full penetration is secured.

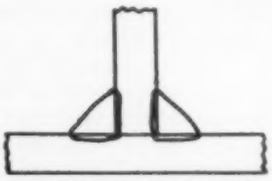
2. SINGLE V BUTT JOINT. Used largely for ⅜" plate or thicker. Scarfing and machining costs more than (1) and more electrode used than in (1). Used generally on plates thicker than in (1). Meets all general or usual load conditions.

3. DOUBLE V BUTT JOINT. The cost of machining is greater but less weld metal is used than in (2) Cost of machining and welding should be balanced against each other. Used largely for ½" and heavier, and for all usual loads. (Note that joint is welded from both sides.)

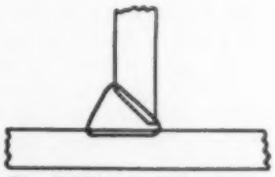
4. SINGLE U BUTT JOINT. Generally used on plates heavier than preceding—½", ⅝" and over. Costs more to machine than single V but requires less electrode. Is welded from one side, except a single bead, which is put in last on opposite side. Meets all usual load conditions. Usually used for best quality work.

5. DOUBLE U BUTT JOINT. Used where welds can be made from both sides—in plate sizes usually heavier than in (4) and where the saving in electrode used justifies the greater machining cost as compared to double V. Used in all types of loads.

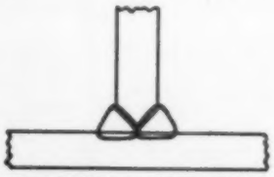
TEE JOINTS



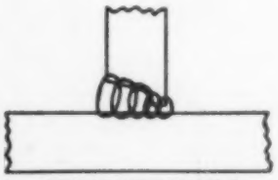
6. PLAIN FILLET WELDED TEE JOINT. May be used for all ordinary plate sizes. No machining of plates. Most satisfactory when welds are in longitudinal shear. For welds heavily loaded transversely by fatigue or severe impact, use with caution.



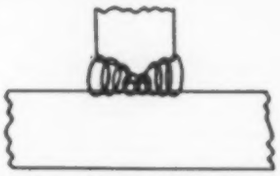
7. SINGLE V TEE JOINT. This is better than (6). For work welded from one side. Generally used on ½" plates or lighter. Costs more for joint preparation but uses less electrode than (6). For more severe load conditions as outlined in (6).



8. DOUBLE V TEE JOINT. Used for heavy plates. Welded from both sides. Uses less electrode than (6). May be used for severe longitudinal or transverse loads of all kinds.



9. SINGLE U TEE JOINT. For usual size plates, generally 1" and heavier. Welded from one side only. Advisable to put in a final finish bead on side away from "U." Machining costs more but takes less electrode than single V. For same load conditions as given under single V. (7).



10. DOUBLE U TEE JOINT. For plates generally 1½" and heavier which can be welded from both sides. More expensive preparation but uses less electrode than (8). For all load conditions, even very severe.

EDGE JOINT

16. EDGE JOINT. Generally used for ¼" or thinner. Not recommended for heavier work. For loads which are not very severe.

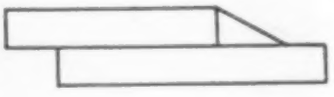
CORNER JOINTS

11. FLUSH CORNER JOINT. Generally used for 12 gauge and lighter. May be used for heavier plates with caution. Not for very severe loads on heavier plate.

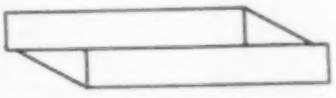
12. HALF OPEN CORNER JOINT. Generally used for 12 gauge or heavier, where welded from one side only. "Shouldering" reduces probability of burning-through and makes for easy welding. May be used for ordinary loads, but with caution for fatigue or impact loads.

13. FULL OPEN CORNER JOINT. Used for all plate thickness when welds can be made from both sides. May be used under severe load conditions, for maximum strength.

LAP JOINTS



14. SINGLE BEAD LAP JOINT. May be used for all sizes of plates where joints are not subject to excessive fatigue or high impact loads.



15. DOUBLE BEAD LAP JOINT. Better than (14). May be used for load conditions more severe than single bead lap joint. Beads should be full size, and joints may be loaded much more severely than (14). The butt joint (5) is the best joint for very severe service but of course is more expensive.

Fig. 3—Drawing Showing the 16 Types of Welded Joints

tion of the materials which welding equipment manufacturers are producing at peak capacity.

The factors which have an important bearing on this situation follow:

1. Select the right type of joint and be careful of fit-up. There is a type of joint (see Fig. 3), best suited to the particular job. A serious disadvantage in waste of weld metal results by using a complicated joint where the more simple type of connection will suffice. Since the type of joint greatly affects the amount of metal required, it is suggested that a study be made to make sure the joint is proper for the particular application. Obviously, the joint to select is the one which meets requirements at the greatest speed and the lowest cost.

Lb./ft. of joint	0.40	0.58	0.80
Cost/ft.	$0.40	$0.58	$0.80
Increase in cost		$0.18	$0.40

Joints and their fit-up should be given most careful consideration, as fit-up affects not only the cost of the welded joint as such, but also the performance of the finished product. As an illustration of the effect upon cost in a very simple fit-up, notice the case shown in Fig. 1, where there is shown a T-weld with $^1/_4$-in. plates. Assume that the cost of deposited metal is $1.00 per pound. Then if the joint is properly fitted up, the cost per ft. of joint (two beads) would be $0.40. If, however, there is a gap between the vertical plate and the horizontal plate of $^1/_{16}$-in. the cost is increased to $0.58 per foot. If this discrepancy is $^1/_8$ in., the cost is increased to $0.80 per foot, resulting in a difference of $0.18 to $0.40 for $^1/_{16}$ in. and $^1/_8$ in., respectively. Obviously money spent in obtaining good fit-up is readily saved in welding.

2. Choose the correct type of electrode. While the general purpose electrode will produce satisfactory welds under virtually every condition, special electrodes as, for example, heavily coated fast flowing types would prove more efficient. The electrode should be chosen with respect to (*a*) physical properties required; (*b*) type of joint; (*c*) position of welding, that is, flat, vertical, overhead or horizontal; and (*d*) condition of fit-up of the work. Recommendations of the equipment manufacturer should be considered.

3. Use an electrode which has and maintains a uniform coating. The electrode coating, if not correct, will cause rejects not only of the electrodes themselves but possibly of the welds produced by their use. It should be remembered that the coating not only produces the protecting shield but it also controls (1) fluidity of the metal; (2) penetration; (3) shape of the beads; (4) physical properties of the deposit; and (5) composition of the deposit.

4. Use electrodes which provide proper physical properties. Electrodes manufactured today are clearly described by the manufacturer in respect to the quality of weld they will produce. Required physical properties of the work at hand should be known and the electrode should be selected to meet these requirements.

5. Use fast flowing electrodes wherever possible. Certain electrodes are manufactured today to permit the fastest possible welding under specified conditions. It is

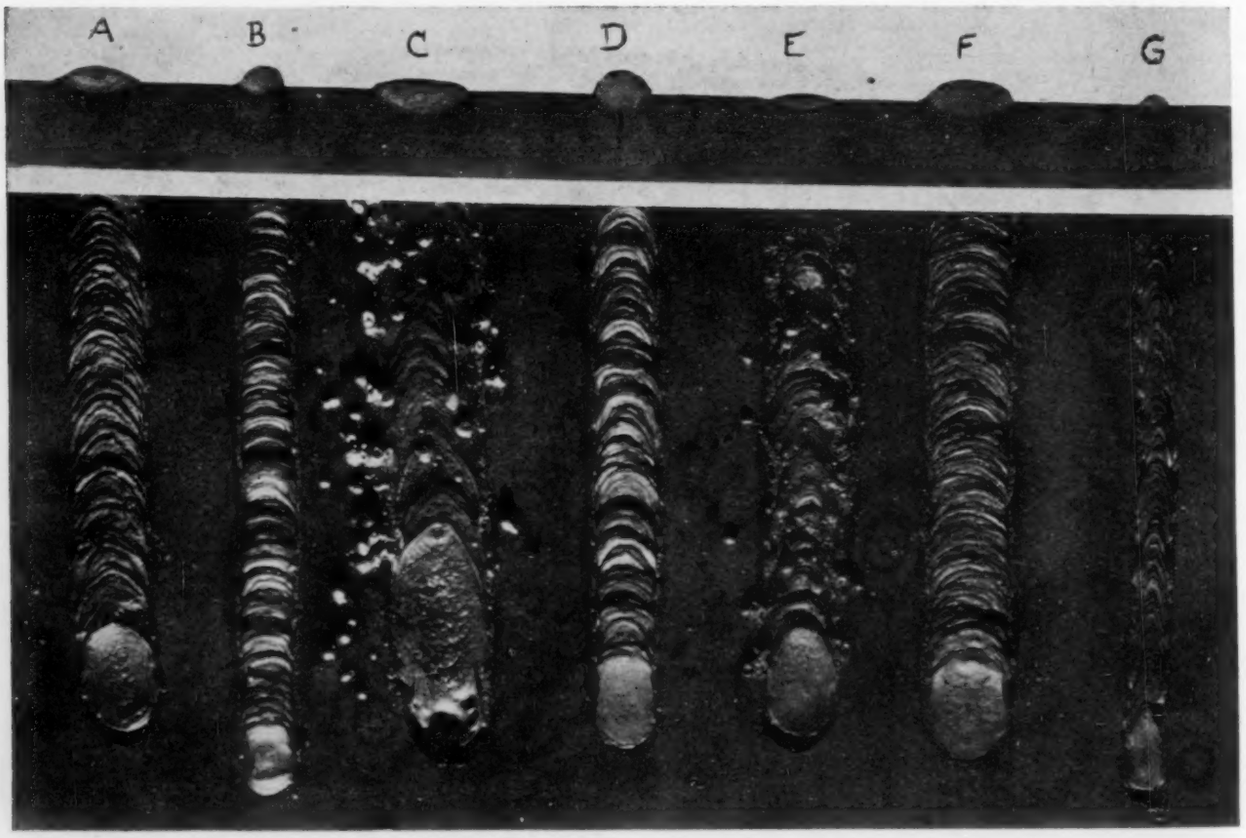


Fig. 4—Plain and Elevation Views of Welds Made with Shielded-Arc Electrode Under Various Conditions

(*A*) Current, voltage and speed normal; (*B*) current too low; (*C*) current too high; (*D*) voltage too low; (*E*) voltage too high; (*F*) speed too low; (*G*) speed too high.

PROPER PROCEDURE: - Characteristics of welds are a good check on electrode conservation. The effect of varying one factor in procedure is indicated below. Note what happens to electrode burn-off rate, weld penetration, appearance of weld and arc sound when the three factors of "arc current", "arc volts" and "arc speed" are varied from "normal".

RESULTING WELD CHARACTERISTICS (SEE FIG. 6)

	"F"	"A"	"B"	"C"	"D"	"E"	"G"
ARC CURRENT	NORMAL	LOW	HIGH	NORMAL	NORMAL	NORMAL	NORMAL
ARC VOLTS	NORMAL	NORMAL	NORMAL	LOW	HIGH	NORMAL	NORMAL
ARC SPEED	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	LOW	HIGH
BURN OFF OF ELECTRODE	NORMAL APPEARANCE COATING BURNS EVENLY	PRACTICALLY SAME AS PRECEDING	COATING IS CONSUMED AT IRREGULAR HIGH RATE-WATCH CAREFULLY	COATING TOO CLOSE TO CRATER TOUCHES MOLTEN METAL RESULTING IN POROSITY	DROPS AT END OF ELECTRODE FLUTTER AND THEN DROP INTO CRATER	NORMAL	NORMAL
PENETRATION FUSION (CRATER)	FAIRLY DEEP AND WELL DEFINED	NOT VERY DEEP NOR WELL DEFINED	DEEP, LONG CRATER	SMALL	WIDE AND RATHER DEEP	CRATER NORMAL	SMALL, RATHER WELL-DEFINED CRATER
APPEARANCE OF BEAD	EXCELLENT FUSION-NO OVERLAP	ON TOP OF PLATE, NOT AS MUCH OVERLAP AS WITH BARE ROD.	BROAD, THIN BEAD-GOOD FUSION	HIGH BEAD NOT AS PRONOUNCED AS FOR LOW AMPS. SOMEWHAT BROADER	WIDE SPATTERED	WIDE BEAD-OVERLAP LARGE. BASE METAL AND BEAD EXCESSIVELY HEATED	SMALL BEAD-UNDERCUT-REDUCTION IN BEAD SIZE AND UNDER CUTTING DEPENDS ON SPEED AND AMPERES
ARC SOUND	SPUTTERING HISS PLUS SHARP CRACKLING	IRREGULAR SPUTTERING, SOME CRACKLING	REGULAR EXPLOSIVE SOUNDS	HISS PLUS STEADY SPUTTER	SOFT SOUND PLUS HISS AND FEW CRACKLES	NORMAL	NORMAL

Fig. 5—Table of Weld Characteristics Made with Proper and Improper Procedure

obvious, therefore, that electrode and, hence, time will be saved if these fast flowing types are used wherever practical.

6. Select an electrode which keeps splatter and slag loss at a minimum. Since all splatter is a waste of weld metal, the importance of this is obvious. It should be realized that the splatter loss of the electrodes vary and care should be taken to avoid use of those which have excessive losses.

7. Wherever possible use electrodes which produce flat beads. It is a waste of welding electrode to deposit any more metal than is required. Not only is the welding electrode itself wasted but useless time is required to remove the excess metal from the welded joint.

8. Select the right size electrode. The largest diameter electrode which can be used effectively is the best from the standpoint of electrode conservation. The saving runs up to 40% per pound deposited, for example, when $^1/_4$-in. is used instead of $^5/_{16}$-in. (See Fig. 2.)

9. Use long electrodes in the larger size. The obvious result is the reduction in the number of stub ends and in the time saved by eliminating interruptions to change rods. The 18-in. length should be used in $^1/_4$-in. and larger sizes.

10. Do not bend electrodes. This generally unnecessary habit will waste from $^1/_4$ to $^1/_3$ of the electrode. Use electrodes straight and get the maximum of deposited weld metal from each rod.

11. Use proper voltage and current settings. Every electrode manufactured is designed to operate at a certain voltage and within a specified current range. If current is too high or too low, it will manifest itself either in excessive splatter loss or inferior welds (see Fig. 4), having improper fusion and penetration. (Also see Figs. 5 and 6.)

12. Follow the procedure specified for the electrode. Accompanying each different electrode manufactured are detailed specifications regarding procedures to be followed. These specifications have been prepared carefully by the electrode manufacturer and, if followed consistently, will prevent waste of electrode and assure high-quality welding.

13. Avoid using an excessive number of beads. If one bead of weld metal will meet design requirements, it is obviously a waste of electrode to add additional beads. This same applies to applications where two beads suffice. Additional beads are simply a useless waste of electrode.

14. Use electrode down to minimum stub end. Remember that the electrode can be used the entire length of its coated surface. Leaving any more than a minimum stub end is an obvious waste. By using care in gripping the electrode at its extreme end in the holder and burning it down to the maximum extent, the operator is rendering a patriotic service in saving electrode.

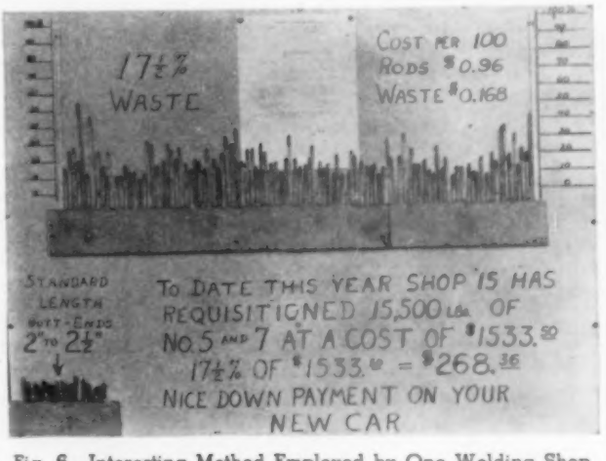

17½% WASTE
COST PER 100 RODS $0.96
WASTE $0.168
STANDARD LENGTH BUTT-ENDS 2" TO 2½"
TO DATE THIS YEAR SHOP IS HAS REQUISITIONED 15,500 Lbs. OF NO. 5 AND 7 AT A COST OF $1533.50
17½% OF $1533.50 = $268.36
NICE DOWN PAYMENT ON YOUR NEW CAR

Fig. 6—Interesting Method Employed by One Welding Shop to Illustrate the Effect of Stub End Loss on Electrode Costs

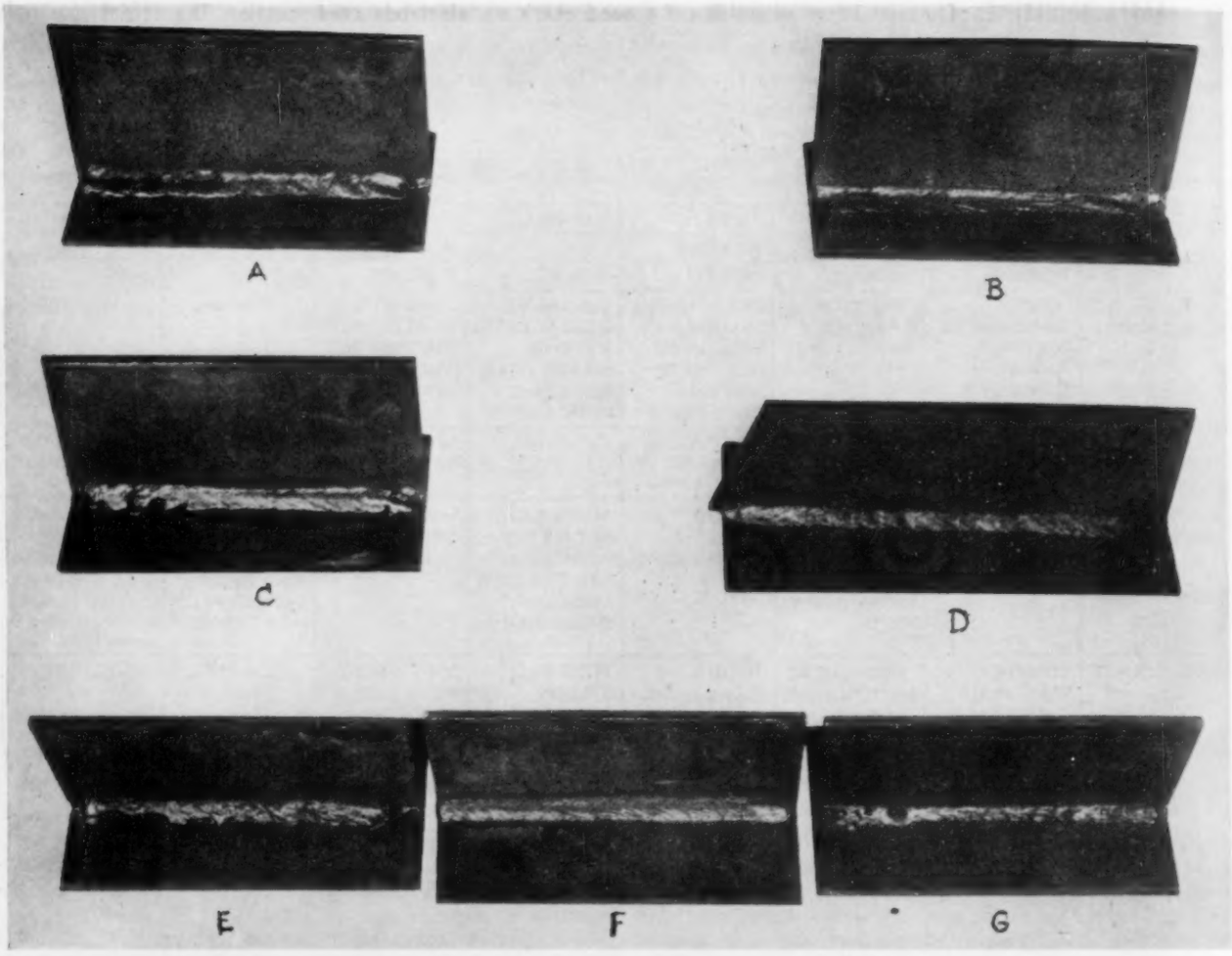


Fig. 7—Fillet Welds Made with Shielded-Arc Electrode Under Various Conditions

(*F*) Current voltage and speed normal; (*A*) current too low; (*B*) current too high; (*C*) voltage too low; (*D*) voltage too high; (*E*) speed too low; (*G*) speed too high.

Just $^1/_2$-in. difference in stub end saves $3^1/_2\%$ on an 18-in. length rod. The accompanying illustration (Fig. 6) shows the great variation in stub ends in one welding shop. As indicated, this waste amounted to $17^1/_2\%$. In cost, for the time covered, it amounted to $268.36.

15. Collect and save stub ends of electrode. At the rate in which welding is being used today in war production, the amount of metal which would be wasted by failure to save stub ends would be tremendous. The average stub end is 2 inches long and this length multiplied by the millions of electrodes used, would constitute the great loss.

16. Use modern high capacity welding generator. Welding generators manufactured today have much higher capacity and much greater efficiency. For example, a modern 40-v. generator was shown to produce 7.7 in. of joint per electrode as against 6.6 in. for an older machine.

SETS OF BOUND VOLUMES OF JOURNAL

In order to provide some of the new members of the Society with an opportunity to complete their library on Current Welding Literature, the AMERICAN WELDING SOCIETY is offering to these new members an opportunity to purchase the last nine bound volumes for the years 1933, 1934, 1935, 1936, 1937, 1938, 1939, 1940, and 1941 at $40.00 a set plus postage. The price to non-members for individual volumes is $6.50 and for the set $45.00 plus postage.

Each bound volume contains a Subject and Authors' Index and is bound in attractive imitation black leather covers. The set probably includes the most important welding information available in the literature.

Current Welding Literature

(*Continued from page 251*)

Shipbuilding. Plate Cutting and Automatic Arc Welding in Ship Construction, F. G. Outcalt and J. M. Keir. Iron Age, vol. 149, nos. 3 and 4 (Jan. 15, 1942), pp. 38–41 and (Jan. 22), pp. 36–42.

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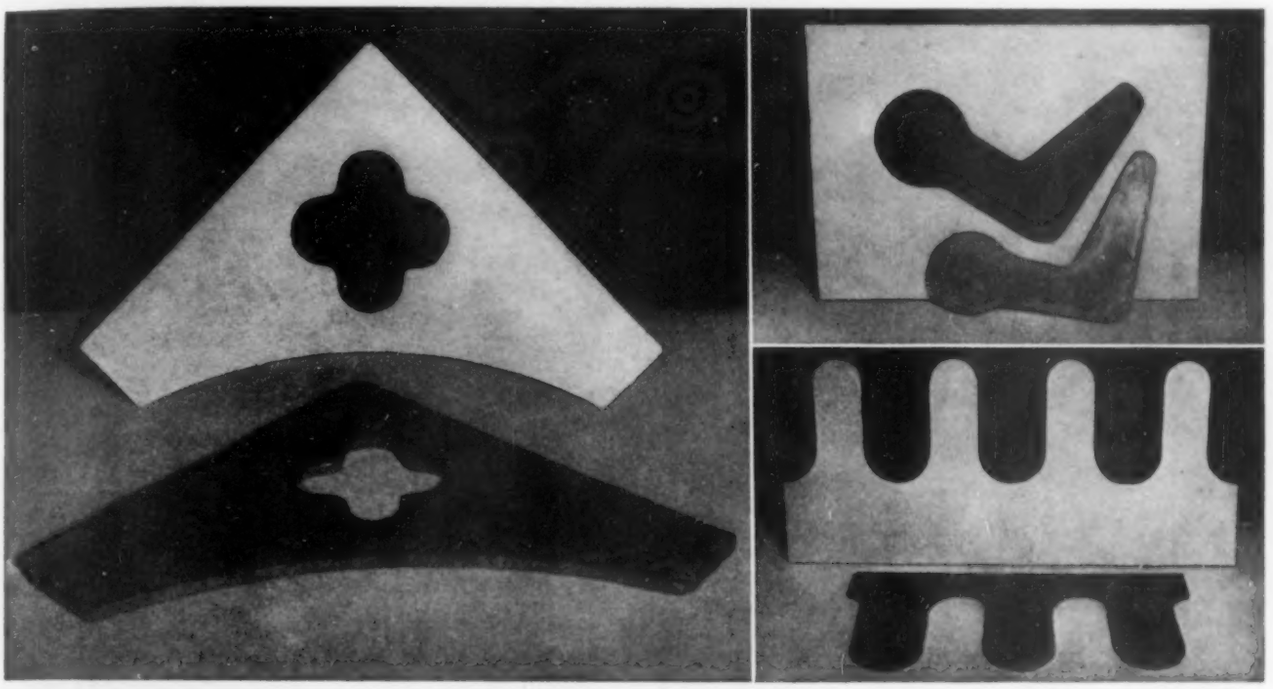
Welding Rods. Selecting Proper Steel Welding Rod. Oxy-Acetylene Tips, vol. 21, no. 2 (Feb. 1942), pp. 34–35.



Typical Examples of Shape-Cut Parts and the Plywood Templets Used to Guide the Hand Blowpipe Are Shown Here: (Left) Ornamental Gusset Plate (Upper Right) Dog and (Lower Right) Expansion Joint for Bridge Floor

Improving the Accuracy of Hand-Cutting Operations

Four Homemade Devices Designed to Increase the Range of Work of Hand-Cutting Blowpipes

By H. H. Moss*

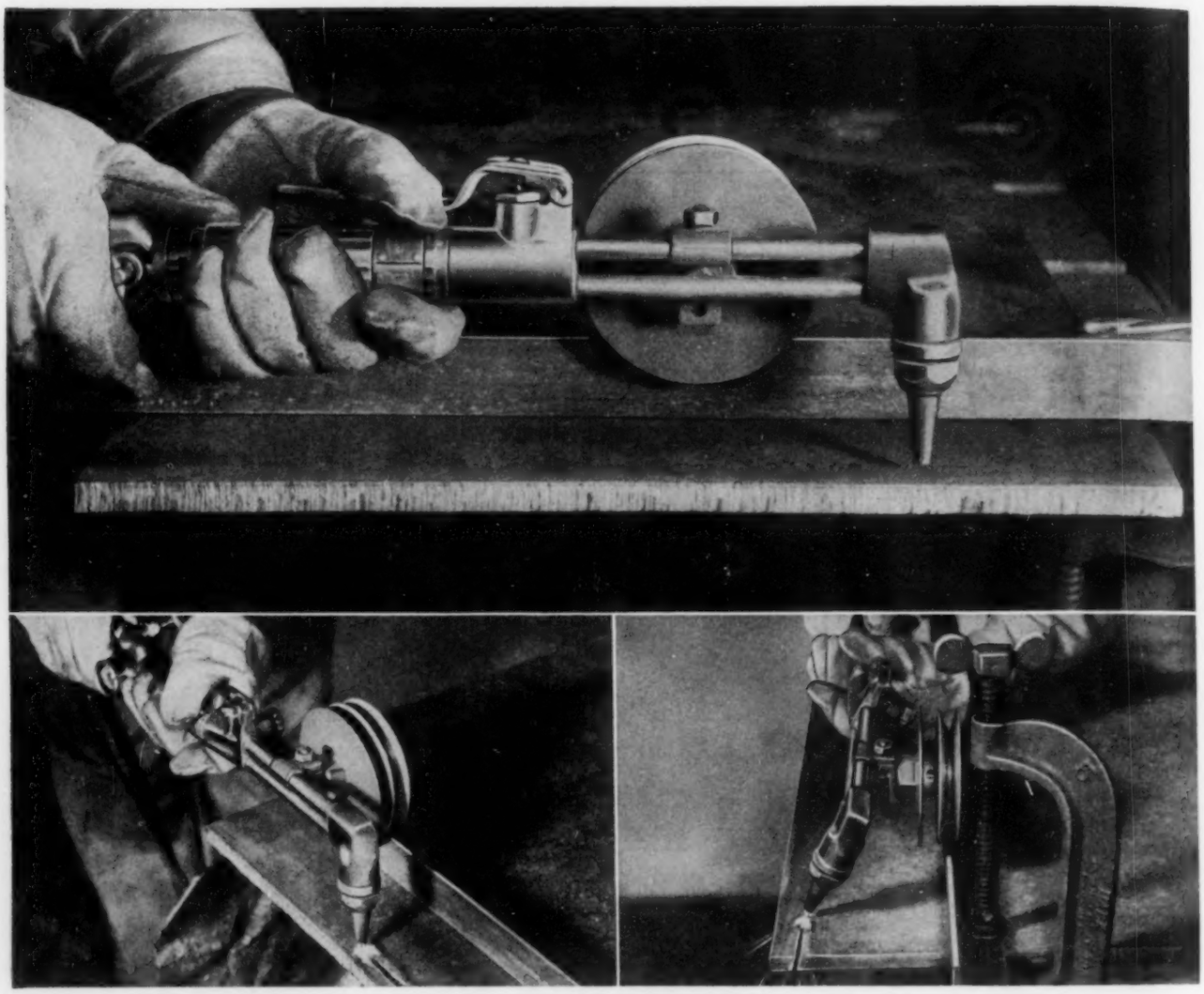
IT is the purpose of this article to describe a number of devices that can easily be made in any shop for further increasing the scope as well as the accuracy of the hand-cutting blowpipe. With these devices, shops not equipped with a cutting machine can handle a wider range of work with greater facility.

As illustrated on the following pages, there are four of these devices—one for straight lines, one for small circles, one for large circles and one for shape-cutting. Each of the devices can be easily and inexpensively constructed out of readily obtainable materials, such as stock angles and rods, and bronze-welded bolts, nuts and washers. Not only do they make possible improved workmanship in the cutting of straight lines, circles and shapes, but also there is a saving in time and gases because the cutting operation is speeded.

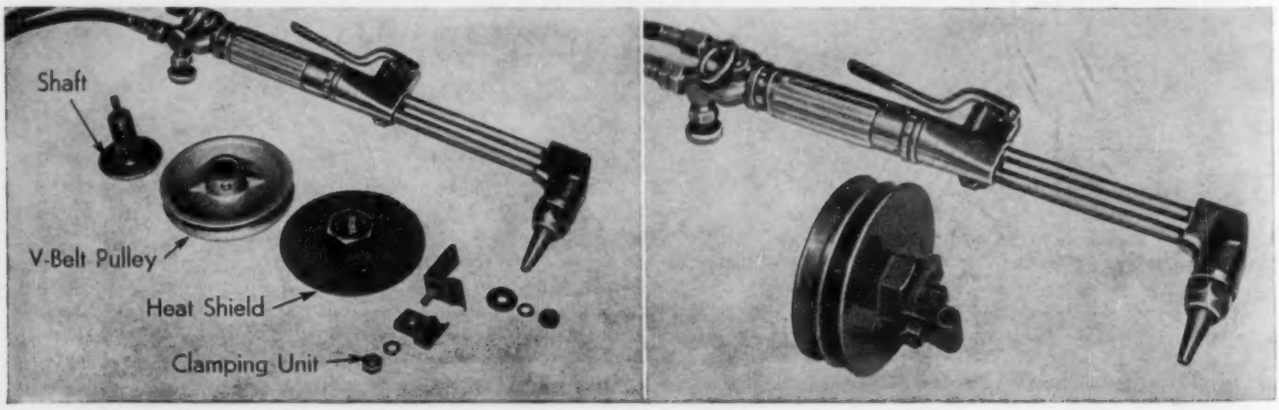
While general principles of construction for each device are quite apparent in the photographs, detailed working drawings, giving full instructions as to how these home-made devices are constructed, are available for those wishing to follow the designs exactly.

* The Linde Air Products Company, New York, N. Y.

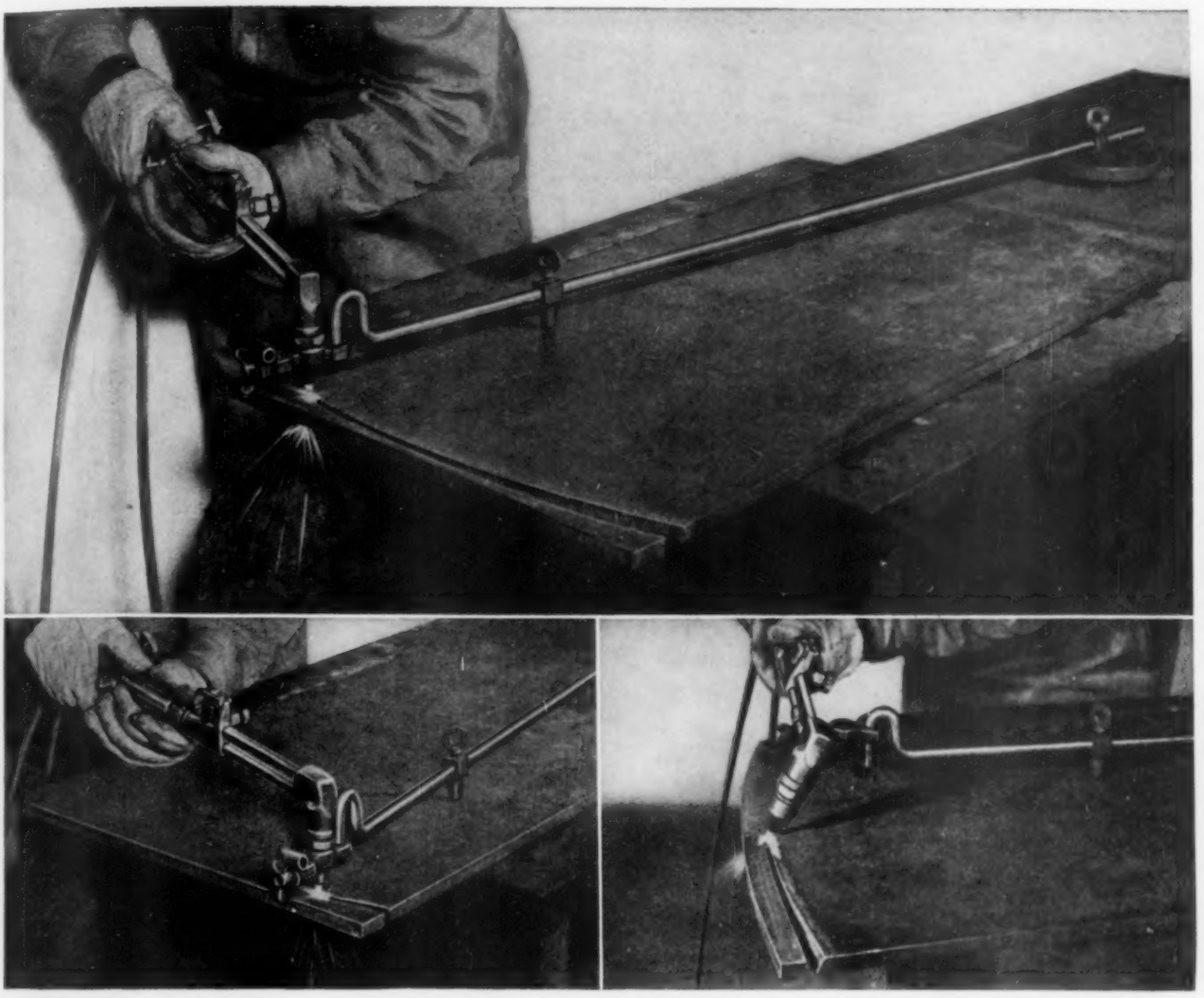
Straight-Line Cutting



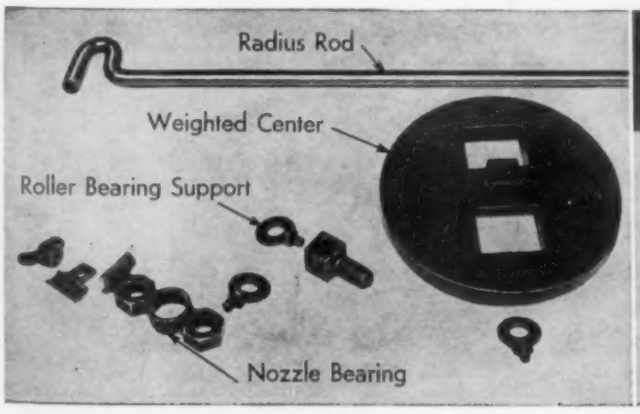
This Simple Guide for Straight-Line Cutting Consists Essentially of a V-Belt Pulley Wheel Which Attached to the Blowpipe and Rides on an Angle Iron. Between Blowpipe and Pulley Is a Disk of $^{1}/_{16}$-In. Steel Which Serves as a Heat Shield. The Shaft Consists of a $^{3}/_{4}$-In. Machine Bolt Washer Welded in Place of the Head. The $^{3}/_{4}$-In. Hex. Nut Is Bronze-Welded to the Heat Shield. The Clamp Is Made by Splitting a Piece of $^{1}/_{4}$-In. Pipe and Welding the Parts to Two Extension Pieces

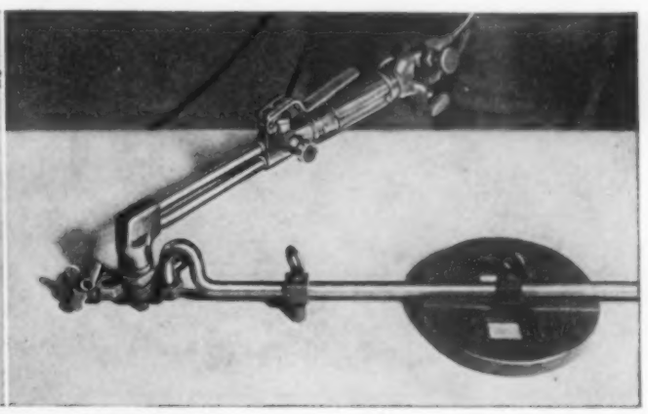


Large-Diameter Circles

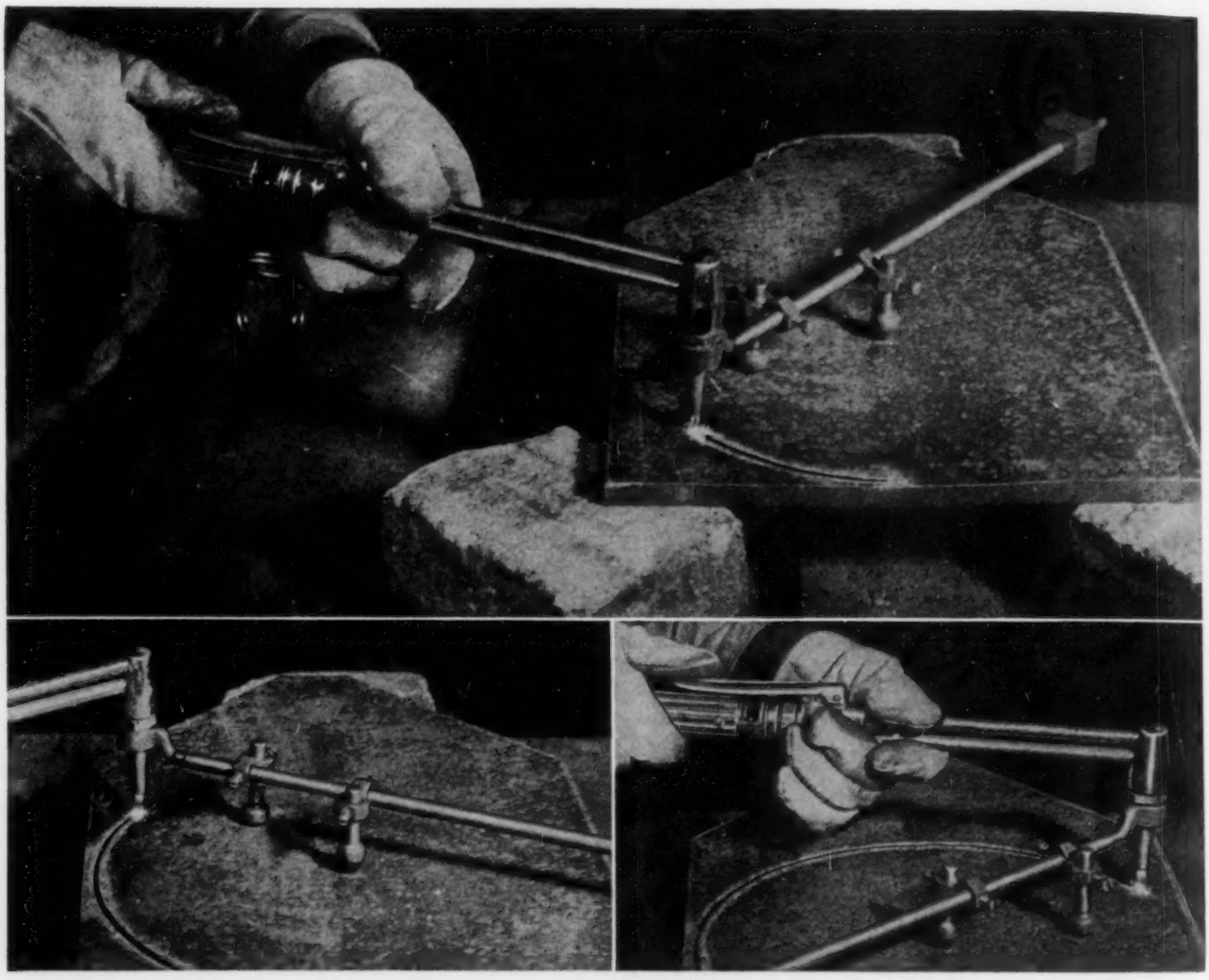


This Radius Rod Is Designed to Cut Circles from 1 or 2 Ft. Up to 10 or More Feet in Diam. It Consists of a $^1/_2$-In. Rod to Which Are Attached with Setscrews a Weighted Center and a Roller-Bearing Support. The End of the Rod Is Shaped in the Form of a Gooseneck to Permit Vertical Adjustment of the Clamping Unit for Different Kinds of Tips. The Blowpipe Bearing Consists of a Sleeve Welded to the Standard Nozzle Nut. As Shown, the Clamping Unit Makes Possible Bevel Cuts as Well as Vertical Cuts

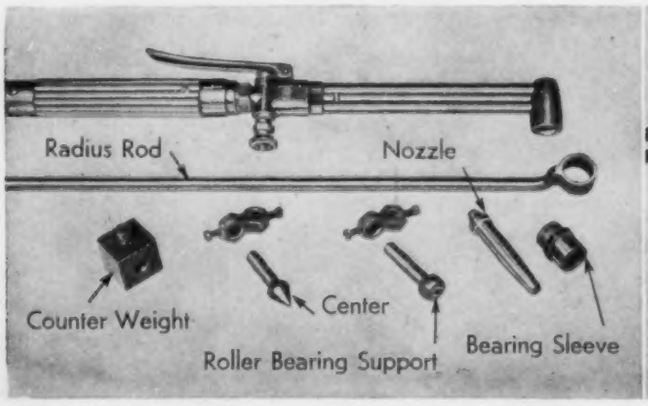


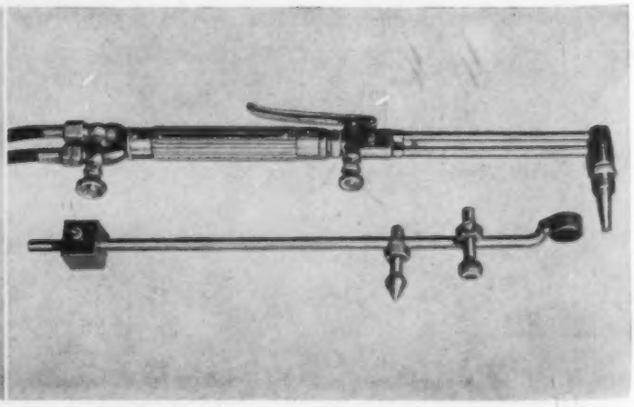


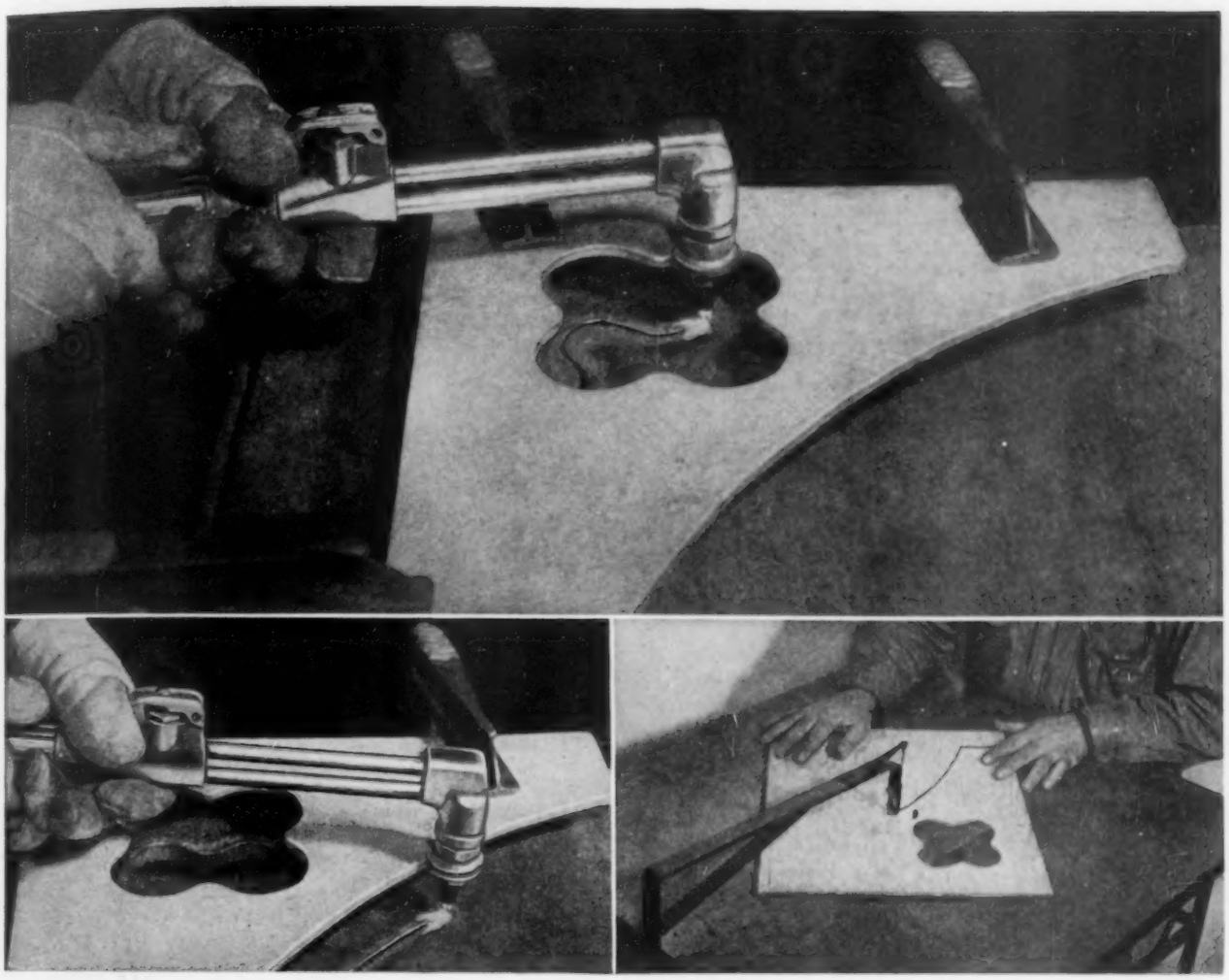
Small-Diameter Circles



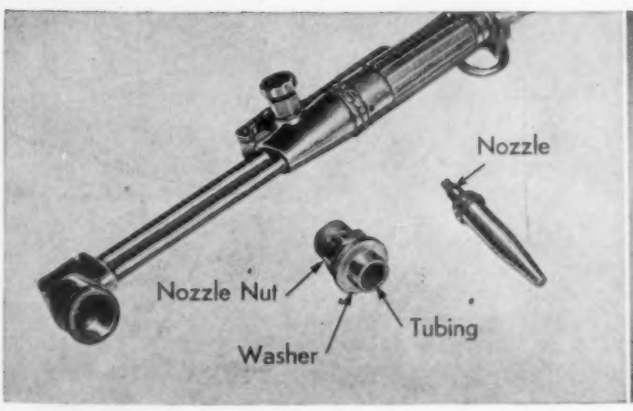
This Radius Rod Makes Possible the Accurate Cutting of Circles from $2^1/_2$ to 36 In. in Diam. It Consists of a $^3/_8$-In. Round Rod Bronze-Welded at One End to a Collar Made from a Piece of Pipe. Fitting Inside This Collar and Acting as a Guide Bearing for the Cutting Nozzle Is a Smaller-Diameter Sleeve Made from a Piece of Pipe and Welded to the Blowpipe Nozzle Nut. The Center and the Roller-Bearing Support Are Both Adjustable Vertically and Horizontally. The Roller Bearing Consists of a Ball Which Rides in a Nut and Is Held in Place with a Washer, the Hole of Which Is Slightly Smaller in Diameter Than the Ball. A Counterweight Helps to Keep the Radius-Rod Center in the Center Mark Punched in the Plate

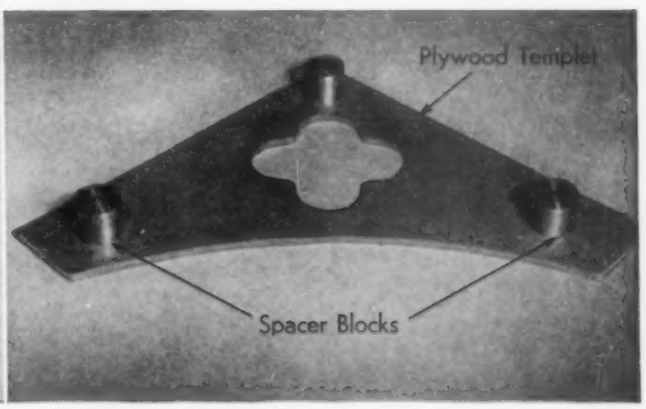






These Photographs Show a Method for Guiding the Hand Blowpipe When Close Cutting Tolerances Are Required, or When a Number of Identical Shapes Are to Be Produced. The Guiding Unit Is a $^1/_4$-In. Thick Plywood Templet ($^1/_2$ In. Thick for Large Templets, to Prevent Warpage). The Shape to Be Produced Is Laid Out on Plywood $^3/_8$-In. Undersize to Provide for Half the Guide-Unit Diameter. The Templet Is Then Cut Out with a Home-Workshop Type of Jig Saw. Edges Are Smoothed with a File and the Templet Is Made Heat-Resisting with Two Coats of Aluminum Paint. The Templet Is Spaced 1 to $1^1/_4$ In. from the Plate to Be Cut with Small Steel Separator Blocks and Is then Clamped Firmly in Place. This Provides Space for Exhaust Gases to Escape. A Washer and Piece of Tubing Welded to the Nozzle Nut Make Up the Unit Which Rides Along the Templet Edge During Cutting





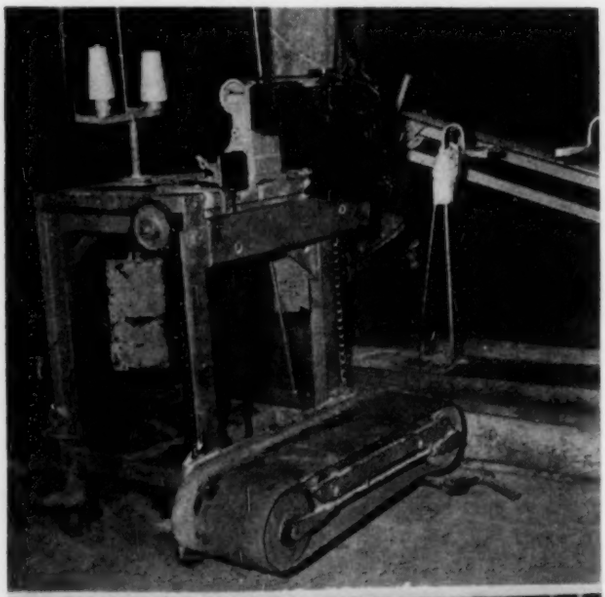
Welding Design Saves Steel

By A. F. Davis*

Sugar Weighing and Packaging Machines Are Arc Welded

ARC welding—the time, money and weight saving process widely used in the construction of great structures such as bridges and ships—lends itself equally as well to precision equipment. An example of this is the sugar weighing and packaging machinery manufactured by J. D. Merrifield & Son, Rocky Ford, Colo.

Fig. 1—The Design of This Bag-Closing Machine Was Improved by Merrifield by Application of the Arc-Welding Principle



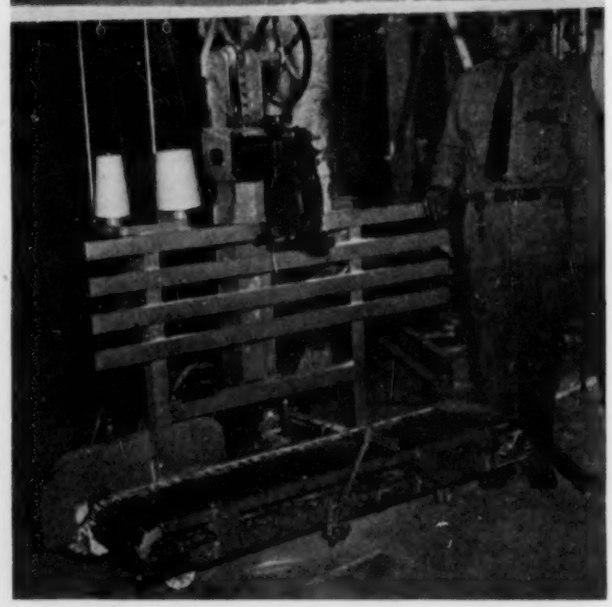


Fig. 2—Merrifield and His Improved Sugar Bag-Closing Machine

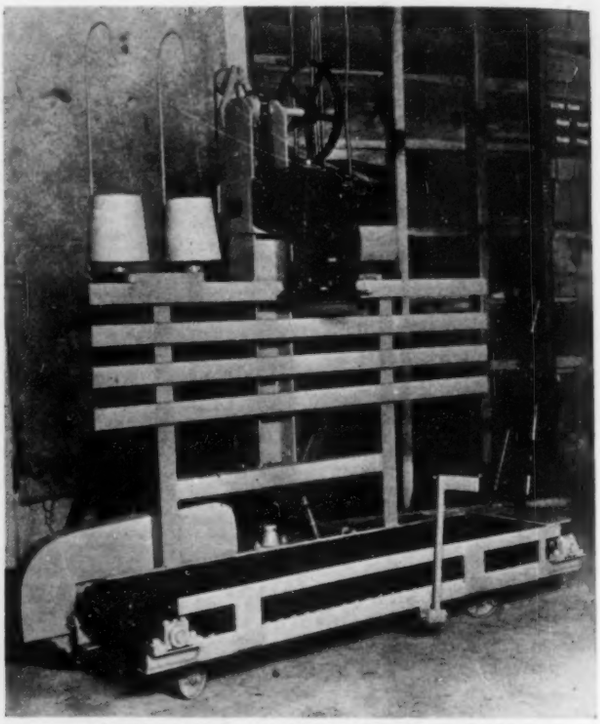


Fig. 3—Another View of the Merrifield Arc-Welded Bag-Closing Machine

Merrifield, a master mechanic, finds that in designing these precise machines he can improve the design, reduce the cost and increase the strength by the application of arc welding.

Figure 1 is a picture of a bag-closing machine, the design of which was improved by Merrifield by the use of arc welding. This machine was manufactured and sold by another company. In Fig. 2 may be seen Merrifield's design, with its designer standing beside it. This machine is used to close 100-lb. sugar sacks. This welded machine can be built and sold for about $100 less than the other design. It also is lighter and easier to operate. Another, more detailed view of the Merrifield machine is shown in Fig. 3.

Another machine in the construction of which arc welding is used extensively is the sugar packaging and weighing machine shown in Figs. 4 and 5. This machine automatically weighs and feeds sugar into sacks of capacity ranging from 2 to 25 lb. It also incorporates a sewing machine to close the bags. A system of electric control is interlocked in such a manner that accurate foolproof weighing is assured.

The machine packages, weighs and sews 30 of the 2 or 5-lb. packages per minute, 25 of the 10-lb. packages and 10 per minute of the 25-lb. sacks.

* Vice-President, Lincoln Electric Co., Cleveland, Ohio.

Fig. 4—This Packaging and Weighing Machine, Designed by Merrifield, Is Arc Welded Also. This Permits Light, Strong, Economical Construction and High Precision

Fig. 5—Another View of the Merrifield Packaging and Weighing Machine

In Merrifield's machine, the weighing is accomplished by a poise beam supported by flexible tempered steel links. This eliminates the customary but troublesome knife edges, the friction of which vary when exposed to sugar or sugar dust.

The machine is electrically driven, instead of using the weight of the sugar in the weighing bucket for operating the filling and emptying gates of the weighing bucket. This design change was made to eliminate the effect of sugar dust, sugar grains or a coating of sugar glaze.

Oil Machinery Manufacturer Reduces Cost and Speeds Production by Arc Welding

THE American Manufacturing Company, Fort Worth, Texas, manufacturers of oil pumping machinery, has found that arc welding speeds production and reduces costs in the fabrication of equipment used to draw the "black gold" from the ground.

One of the company's pumping units, clean in appearance and strong in construction, is shown in Fig. 6. Arc-welded fabrication was used extensively in the manufacture of many of the parts used in this unit.

Fig. 6—Completed Oil Pumping Unit Produced by the American Manufacturing Company. Arc Welding Was Used Extensively in Its Construction

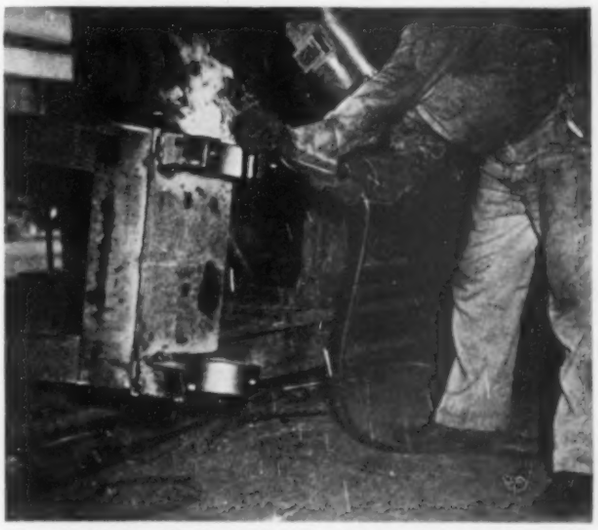


Fig. 7—Welder Works on Bearings Fastened to the Top of the "Sampson" Post of a Pumping Unit

Fig. 7 shows a welder at work on bearings fastened to the top of a "Sampson" post by means of the electric arc.

The saddle shaft shown in Fig. 8 fits into bearings similar to those shown in Fig. 7. Figure 8 illustrates the new welded saddle shaft now used by the concern at a savings of more than 26%. This part, which serves as the bearing support for the rocker arm on top of the "Sampson" post, now costs $7.42 complete and weighs

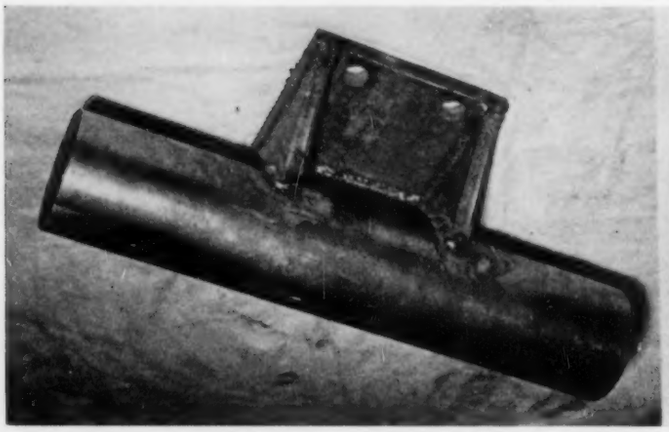


Fig. 8—Arc-Welded Saddle Shaft

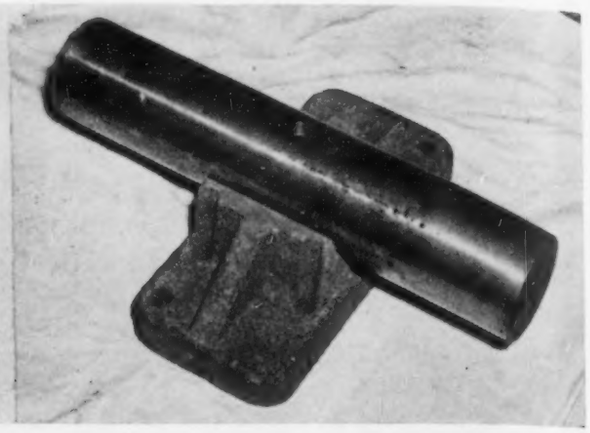


Fig. 9—This Saddle Shaft, Previously Used by the Concern, Cost 26% More to Make than the Arc-Welded One Shown in Fig. 8

147 lb. The former construction, illustrated in Fig. 9, cost $10.15 and weighed 199 lb.

The company previously used a Pitman arm constructed as shown in Fig. 10. This comprised two bearings bolted together. These parts cost $9.42 and weighed 86 lb. The arc-welded type of Pitman arm now used is illustrated in Fig. 11. The part on the end now is cut from 1-in. plate by flame cutting and is arc welded to the I-beam of the Pitman arm. It costs $7.20 and weighs only 84 lb.

A similar saving in weight and cost was made by the company in the construction by arc welding of the equalizer shown in Fig. 12. The all-welded equalizer shown in the foreground costs $24.77 and weighs 165 lb., or 15 cents per pound. The former construction is shown in the background. This type cost $34.11 and

Fig. 10—The Concern Reduced Cost and Weight by Changing the Design of This Pitman Arm Previously Used. Compare with Fig. 11

Fig. 11—Arc-Welded Pitman Arm. The Part on the End Is Flame Cut from Plate and Arc Welded to the I-Beam. Compare with Fig. 10

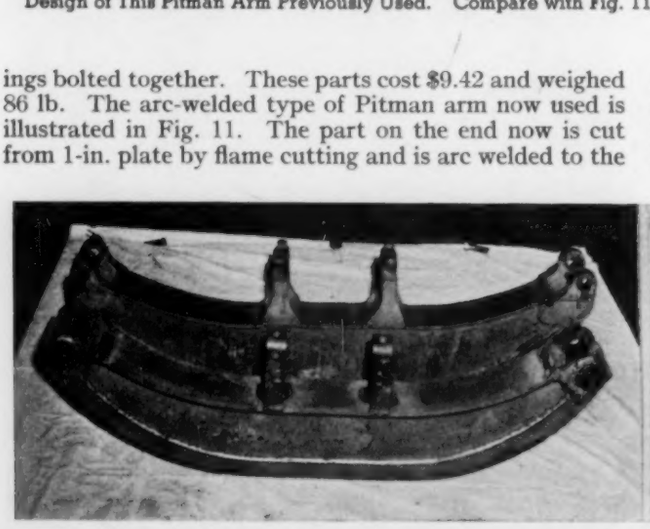


Fig. 12—Two Equalizers Are Shown in This Illustration. The Arc-Welded One in the Foreground Now Is Used at a Cost Savings of Almost $10

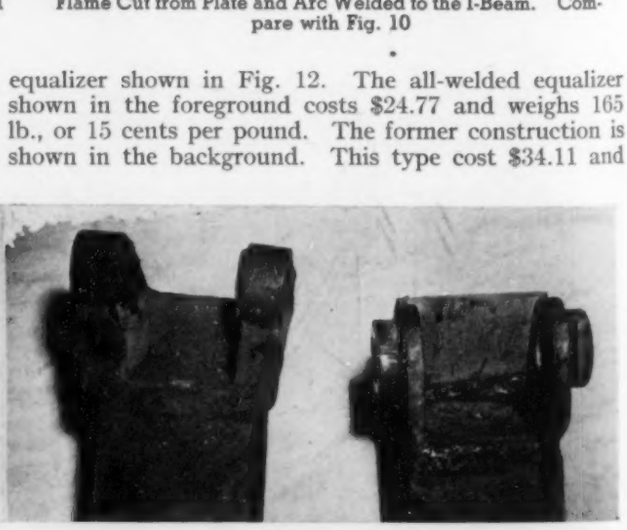


Fig. 13—A View of the Ends of the Equalizers Shown in Fig. 12. The One on the Right Is All Arc Welded

Fig. 14—Equalizer Ends and Yokes Before They Were Welded to the Equalizer Bodies. The Pieces on the Right Are Arc Welded

Fig. 15—How the Concern Fabricates a Mule-Head for a Pumping Unit. The Curved Plate Is Bent by Means of the Chain and Then Arc Welded in Place

weighed 205 lb., or about 17 cents a pound. This saving was chiefly accomplished by adoption of welding to the construction of the yokes and ends of the equalizers, the latter shown in Fig. 13. The main I-section was welded in both cases.

Further details of the equalizer ends before they were arc welded to the equalizer I-section, and a view of the yokes, may be seen in Fig. 14. The yokes are shown at the top and the ends at the bottom of this photograph. The present arc-welded yoke, shown at the top right, is merely a flame-cut part made from a 2-in. steel plate. This yoke, welded to the equalizer, costs a total of $1.92. The former construction shown on the left cost $5.29. The equalizer ends weigh 17 lb. for the former method and 12 lb. for the arc welded.

Fabrication of a mule-head for a pumping unit is shown in Fig. 15. This is made from flame-cut plate and assembled in the fixture illustrated. The plate shown curved along the top is formed by tightening the chain over the top by the geared winch shown on the end of the table. The round bars at the front end and center of the curved plates are tack welded temporarily to provide a riding surface for the chain. Another such piece is welded to the far end and after the plate has been bent into shape it is tack welded in place. The chain is then removed as shown in the picture and the welding is completed. Sides of the mule-head are reinforced by $1^1/_2$- by $1^1/_2$-in. angles as shown.

This piece also is shown in Fig. 6. It is the riding surface for the cables from the sucker rod going into the well. Its purpose is to keep the rod moving in a straight line, up and down.

Welders Show Designing Ingenuity in Utilizing Scrap Pipe

WELDERS throughout the country are using great ingenuity in the building of structures from scrap pipe, large quantities of which are available despite scarcity of other materials because of the war effort.

An example of this is the cleanly designed, arc-welded

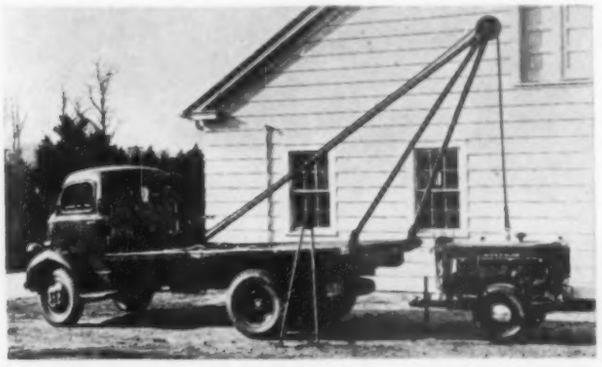


Fig. 16—This Truck Crane Was Designed and Built by a Welder. The Back Leg Telescopes to Adjust the Angle of the Boom. Arc Welding Was Used Throughout

Fig. 17—Welder J. E. Nadeau of Timmins, Ontario, Designed and Welded This Clean-Looking Idler Tower

crane boom shown in Fig. 16. This was designed and built from scrap pipe by Welder William W. Willock, Jr., of Syosset, N. Y.

The boom is made of $2^1/_2$-in. pipe and some scrap angles and plate. It is all welded except for bolting to the truck.

The back leg telescopes to adjust the angle of the boom by putting a pin in different holes in the telescoping members. For lifting heavy loads, Willock uses a snatch block in the load line by hooking the free end of the rope to a "U" on the back leg near the head sheave.

Leaning against the truck is a small welded "A" frame, also made from scrap pipe, used to hold up the rope in raising the boom from the horizontal position in which it is transported. This "A" frame has pivoted feet which pin into holes near the rear of the truck body. When the boom is halfway up, a pin is inserted in the back leg and the "A" frame taken away. The boom goes up the rest of the way easily.

As the truck has a capstan winch for rope, instead of a drum for cable, it was necessary to mount an extra sheave at the foot of the back leg to hold the rope down and keep it from fouling on the winch head.

The lifting rope of the crane is shown attached to the lifting loop of the welding machine. This machine is mounted on a cut-down house trailer axle with underslung springs mounted outside the welder frame and cranked axle. This keeps the center of gravity low and permits the use of a narrow tread.

According to Willock, this trailer has been towed at 40 miles an hour without any ill effects.

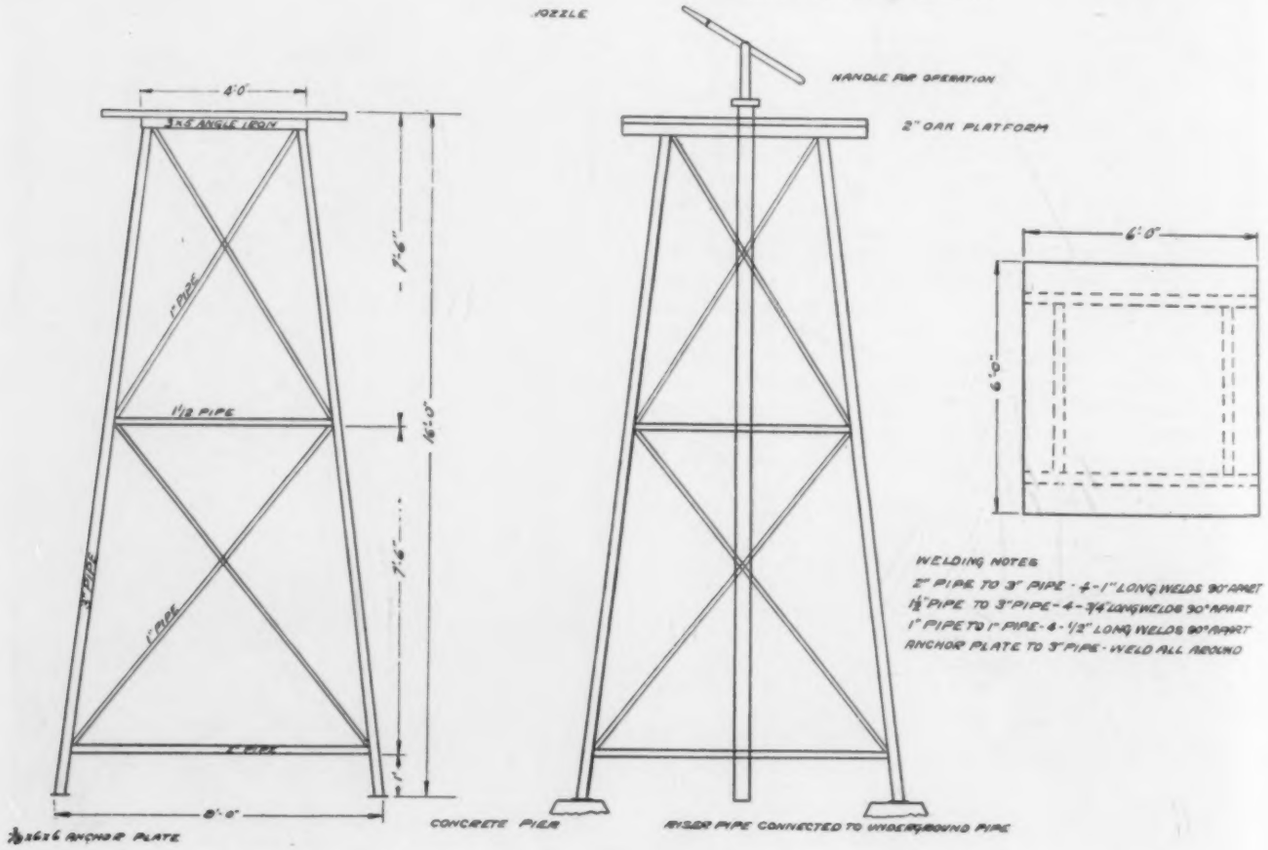
Another interesting structure built by a welder is the idler frame shown in Fig. 17. This tower was fabricated by welding scrap pipe. It is 35 ft., 6 in. high. The legs are of 3-in. pipe and the cross members of 2-in. pipe. For the "X" bracing 1-in. pipe was used.

This idler was built by J. E. Nadeau of Timmins, Ontario.

Welded Fire Control Towers

HERE is the simple construction plan, used throughout the lumber yards of the P. H. Gladfeller Co. of Spring Grove, Pa., to build all-welded fire control towers. All pipe and iron used on these seven and a half foot towers were taken from the scrap pile. Mounting ladder, not shown in the drawing, was welded on from $^3/_4$-in. x 8-in. round iron. One of these inexpensive fire towers can be turned out by two welders in eight hours time. It is expected that these strongly constructed towers will become very popular in plant yards for bomb fire precautions.

Photo courtesy Hobart Bros. Co.


NOZZLE
HANDLE FOR OPERATION
2" OAK PLATFORM
4'-0"
3"x3" ANGLE IRON
1" PIPE
1 1/2 PIPE
3" PIPE
1" PIPE
8'-0"
6'-0"
6'-0"
WELDING NOTES
2" PIPE TO 3" PIPE - 4-1" LONG WELDS 90° APART
1 1/2" PIPE TO 3" PIPE - 4-3/4" LONG WELDS 90° APART
1" PIPE TO 1" PIPE - 4-1/2" LONG WELDS 90° APART
ANCHOR PLATE TO 3" PIPE - WELD ALL AROUND
CONCRETE PIER
RISER PIPE CONNECTED TO UNDERGROUND PIPE

Straight-Line Production of Liberty Cargo Ships

By J. A. Corlett*

TO gain all possible speed in the feverish race against time, a combination of two of the world's best production methods is being used by the California Shipbuilding Corporation, Los Angeles, builders of Liberty cargo ships.

Fig. 1—Single-Operator Motor-Generator Arc Welders in Use in Plate Shop of the California Shipbuilding Corporation, at Los Angeles Harbor, Calif.

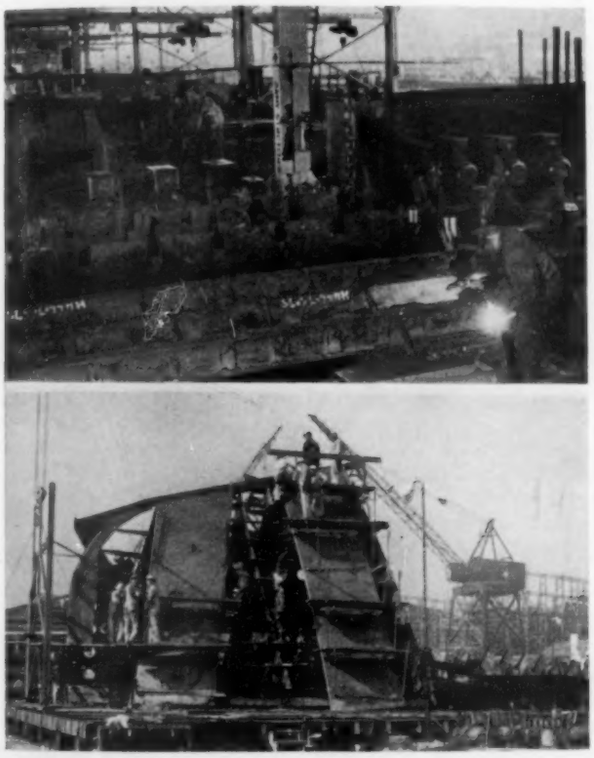


Fig. 2—Four-Operator 150/200-Ampere Resistor Station and Single-Operator Motor-Generator Arc Welders Used in Fore-Peak or Bow-Assembly of Liberty Ship

First, the yard and ways are laid out to permit orderly progression of both work and material from start to finish. Second, arc welding is used almost exclusively as the method of fabricating all steel work. Sufficient arc-welding equipment is installed at this yard to keep over 3000 men busy operating more than 1000 welding arcs 24 hours a day.

The first step in the building of these Liberty ships is to unload the steel from the railway siding into the plate shop, where it is cut and formed. Here, also, some of the smaller subassemblies such as ribs and bow substructures (Fig. 1) are fabricated with the aid of both 200-amp. and 400-amp. d-c single-operator arc welders, the former being used largely for tacking.

* Los Angeles Office, General Electric Company.

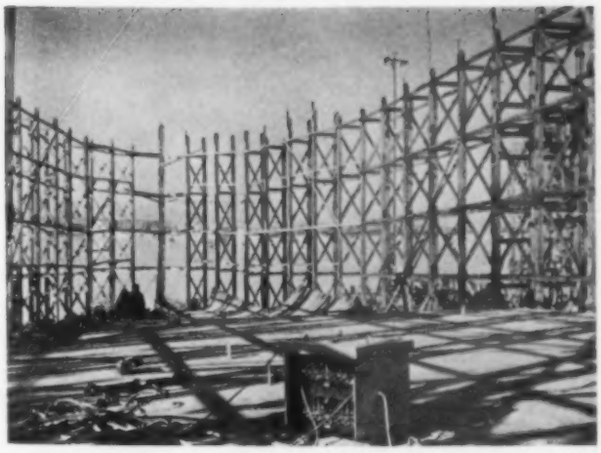
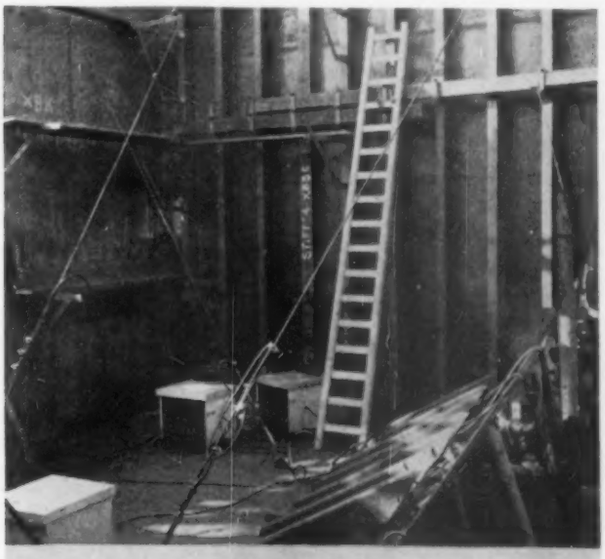


Fig. 3—Four-Operator 150/200 Ampere Resistor Station in Use on Welding of False Bottom of Liberty Ship

From the plate shop, material moves onto assembly platforms where the major subassemblies are fabricated. Bow assemblies are erected in an inverted position as illustrated in Fig. 2. Rib sections, deck sections and

Fig. 4—Four-Operator Resistor Station Used in Erection of Bulk Heads and Sides of Liberty Ships



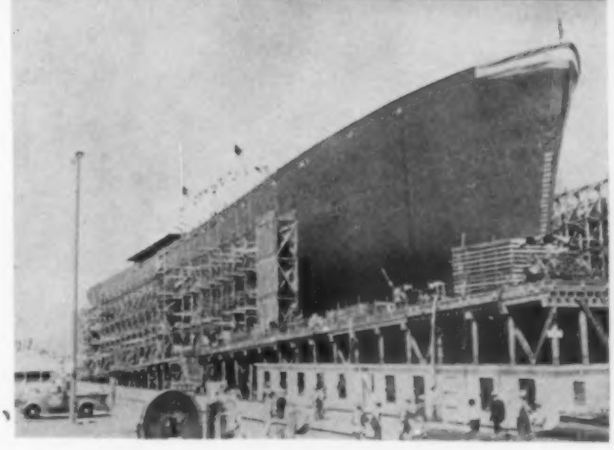


Fig. 5—Ten-Thousand-Ton Marine Freighter Preparatory to Launching

bulkheads also are fabricated on these assembly platforms with the aid of 300-amp. arc welders.

Progressing to the shipways, the subassemblies are erected and the hull takes shape. The bottom and false bottom are laid on the ways (Fig. 3), after which sides and bulkheads are erected (Fig. 4). Here the greater part of the welding current is furnished by multiple-operator d-c arc welders located beneath the ways in a neat, clean generator room.

Decks and hatchways are then installed to complete the hull and make ready for launching. Portable adjustable resistors used with multiple-operator arc-welding systems permit operators to increase or decrease welding current to suit their needs. Each of these resistor stations provides control for four arcs.

Finally, another Liberty ship is ready to be outfitted and join the fast-growing fleet (Fig. 5). It has been estimated that approximately 35 miles of arc-welded joints are made by manual operation and more than $7\frac{1}{2}$ miles by automatic operation in building each of these 10,000-ton cargo carriers.

Preheating Aids Cast-Iron Repair

By R. E. Baker*

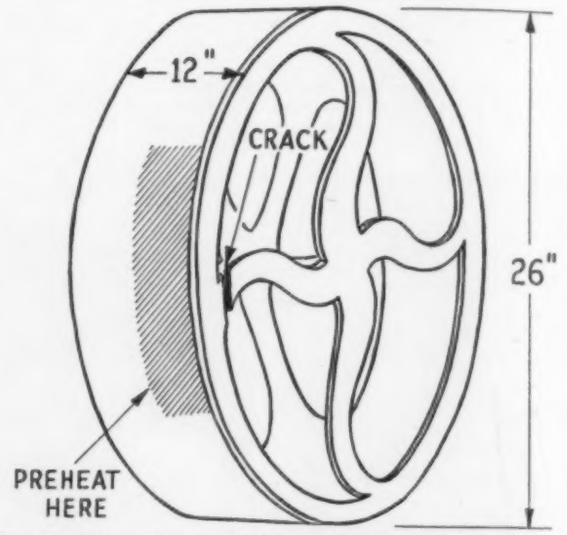
FACED with the reclamation of a number of cracked roller castings, a job welding shop developed an interesting preheating and bronze-welding procedure that resulted in a particularly efficient repair and with a minimum of residual stress in the castings.

The rollers, measuring 26 in. high and 12 in. wide, developed cracks in the spokes which were located close to the rim of the casting. However, a complete repair was made by bronze welding as illustrated below.

Preheating Procedure

The welding operator first beveled the crack by grinding so as to expose clean metal for deposit of the bronze weld metal. The casting was then preheated with a blowpipe along the outer edge of the roller over an area of about one-half the width of the roller face and extending a little more than one-eighth of the circumference on each side of the joint directly over the break. (The preheated area, as indicated by shading, is shown in the accompanying sketch.) The heating served to relieve locked-up stress, and as these areas expanded it caused the two broken edges to pull apart, leaving a $\frac{1}{16}$-in. space.

After preheating, the spoke was bronze welded with a bronze rod. Four times during the welding procedure the operator stopped to peen the bronze metal with a hammer. This served to break up any stresses that might have been caused by the bronze metal as it solidified and attempted to pull together the two broken sections. Peening, in addition to breaking up this pulling action, left the $\frac{1}{16}$-in. spacing between the edges of base metal intact so as to take care of subsequent contraction when cooling. The entire operation required only 20 min. including the beveling, preheating, bronze welding and peening.



The shaded portion in the above sketch indicates the area which was preheated by the blowpipe causing the spoke to expand and leave a $\frac{1}{16}$-in. space.

* Linde Air Products Co., Baltimore, Md.

Here are illustrated three stages in the bronze welding of a cast-iron roller casting: (left) the crack in the broken spoke is beveled and ready for welding; (center) following preheating, the spoke is welded; (right) the completed weld.

THE AMERICAN WELDING SOCIETY

ACTIVITIES – RELATED EVENTS

NOMINEES FOR DISTRICT VICE-PRESIDENTS

New York-New England: E. R. Fish, Chief Engineer, Boiler Division, Hartford Steam Boiler Insp. & Ins. Co., 56 Prospect St., Hartford, Conn.

Middle Eastern: J. H. Humberstone, Welding Eng. Dept., Arcrods Corp., Sparrows Point, Md.

Middle Western: J. D. Tebben, Sales Mgr., Metallurgical Div., P. R. Mallory & Co., Indianapolis, Ind.

Southern: K. B. Banks, Asst. Chief Engr., Black, Sivalls & Bryson, Oklahoma City, Oklahoma.

Pacific Coast: P. D. McElfish, Chief Materials Engineer, Los Angeles Division, Standard Oil Co. of Calif., Los Angeles, Calif.

Article V, Section 6, By-Laws: "... The nominations made by the Districts shall be published in the April issue of THE WELDING JOURNAL of the AMERICAN WELDING SOCIETY.

"Independent nominations may be made by a petition of twenty-five (25) or more members sent to the National Secretary not later than May 15th; such petitions for the nomination of District Vice-Presidents shall be signed only by members within the district concerned.

"Only District members shall be eligible to vote for District Vice-Presidents."

PRESIDENT'S MESSAGE

It is usual in the early spring months for those responsible for the administration of local sections of technical societies to give consideration to the policies to be carried out for the year. This year, because of war conditions, it is more necessary than ever to formulate policies of Sections. There is a feeling among some that technical activities are superfluous but those who have been associated with the problems of war production realize that the expansion of industry and the conversion of industrial plants to war manufacture have generated the need for a tremendous educational program.

There are numerous ways jn which this program can be carried out. Of course, much of it must be carried on nationally and is being organized by those responsible for war production. This, however, need not be analyzed here. There are two other means through which this educational program can be developed, one being the voluntary organization of those engaged in a similar line of activity and the other the local organization of technical groups to handle the problems of the community that the Sections serve. The American Society for Metals is developing a local organization as an information center through which the less experienced fabricators may be assisted. It is possible that some of our local sections might render excellent service to their communities by organizing a similar or joint setup. Service of this type is worthy of study.

There remains the problem of keeping our production and design engineers in contact with all developments of industry including the current ones of the war activity. This problem is more important because the responsibility of junior engineers is being fast increased and engineers with previous experience on other lines of activity are being diverted to war production. Of course, the essence of our local section work has been educational but it seems necessary that special consideration be given in each community to the nature of current problems in order that programs evolved be adapted to needs. In some cases, the development of engineering training courses may be a practical solution, in others it may be essential that special lecture or other types of special courses be organized. It is possible that conferences and round table discussions would be good methods of procedure.

The winning of this war depends, to a very considerable extent, upon the initiative exercised by our engineering profession. It is necessary to know the objectives and to conform to the plans of the war effort. Knowing the plans, objectives and local conditions, it is entirely practicable for the engineer of a community to assume a leadership which will greatly expedite and perfect our war efforts.

EXECUTIVE COMMITTEE MEETING AMERICAN WELDING SOCIETY

The Executive Committee Meeting of the A.W.S. was held in New York on February 19, 1942. The following were present: Col. G. F. Jenks, *President*, presiding; C. A. Adams, David Arnott, H. C. Boardman, R. W. Clark, E. V. David, J. H. Deppeler, E. R. Fish, O. B. J. Fraser, D. S. Jacobus, H. O. Hill, J. F. Lincoln, L. S. Moisseiff; F. L. Plummer, member, Board of Directors; C. I. MacGuffie, *Chairman*, Manufacturers Committee; W. Spraragen, *Technical Secretary;* M. M. Kelly, *Secretary;* J. W. Meadowcroft, H. L. Whittemore.

By Laws

Amendment Article VIII, Section 1 (m) "Committee on Awards"

It was voted to amend this Article as follows:

"A Committee on Awards consisting of five individuals, each serving for a period of five years. The appointment shall be arranged in such a way that one member shall retire on the adjournment of each Annual Meeting. The member senior in respect to service shall be Chairman. It shall be the duty of this Committee to make the award and arrange for the presentation of such medals or other awards as may be authorized by the Board of Directors."

1942 Annual Meeting and Welding Exposition

Plans are under way for holding an Annual Meeting in Detroit during the week of October 12th. The size and character of the meeting will depend largely upon the availability of good technical papers and the willingness of members to participate. Some curtailment will be necessary in the entertainment features.

It was voted to approve the recommendation of the Finance Committee that an appropriation, not to exceed $2500, for Annual Meeting expenses be authorized.

Welding Handbook

The *Welding Handbook* Committee presented a comprehensive report showing the status of each chapter and the enormous amount of work needed to bring the second edition of the *Welding Handbook* into print. Every effort is being made to have the book ready for distribution early in June. The President complimented the Committee on its splendid report.

Technical Activities

(1) Appointment Committee on Arc-Welding Standards for Shop-Erected Low Alloy Steel Structures Subject to Dynamic Stresses.

It was voted to approve recommendation of Outline of Work Committee that this Committee be appointed with scope and personnel as follows:

Scope

Preparation of standards for shop-erected low alloy steel structures subject to dynamic stresses, including the following topics: (*a*) joint design, (*b*) welding procedure, (*c*) heat treatment, (*d*) inspection.

Personnel

R. W. Clark (*Chairman*), General Electric Co.
A. G. Bissell, Bureau of Ships.
B. J. Brugge, The Lincoln Electric Co.

Everett Chapman, Lukenweld, Inc.
J. H. Deppeler, Metal & Thermit Corp.
C. H. Jennings, Westinghouse Electric & Mfg. Co.
W. B. Lair, York Safe & Lock Co.
A. J. Raymo, The Baldwin Locomotive Works.
W. W. Schmidt, Rock Island Arsenal.
W. L. Warner, Watertown Arsenal.

(2) Guide for the Appointment and Functioning of Representatives of the AMERICAN WELDING SOCIETY on Technical Committees of Other Societies.

It was voted that rules submitted as Appendix B, Exhibit A, of Agenda of this meeting be adopted by the SOCIETY subject to the unanimous approval of the Outline of Work Committee by letter ballot.

(3) Standards for Welding in Machinery Construction.

It was voted to approve recommendation of the Outline of Work Committee for the withdrawal of the Code for Fusion Welding and Flame Cutting in Machinery Construction (1935 Edition).

(4) Standard Methods for Mechanical Testing of Welds.

It was voted to approve recommendation of Outline of Work Committee to adopt as a standard of the SOCIETY "Standard Methods for Mechanical Testing of Welds" as revised by the Committee on Standard Tests for Welds.

(5) Aircraft Resistance Welding Standards Committee.

It was voted to approve recommendation of Outline of Work Committee that the title of the Aircraft Resistance Welding Standards Committee be changed to Aircraft Welding Standards Committee, and that the scope of the committee's activities be enlarged to cover all processes of welding.

In connection with this recommendation, the President reported that the work of the Committee is about two-thirds completed, and it is expected shortly that preliminary report will be ready for submittal to the members of the Committee for approval, after which it will go to the National Aircraft Standards Committee for approval before submittal to the A.W.S. Committee.

(6) Recommended Practices for Inspection of Welding.

It was agreed to expedite the approval of this report by letter ballot and it was voted to give permission to the Navy Department to preprint this material ahead of the SOCIETY for use of Naval Inspectors.

Finances

The Treasurer called attention to the following: an improvement of more than $1000 in the net worth of the SOCIETY since the beginning of the present fiscal year; an improvement in the actual operations over the budget of $3586.48. The budget made allowance for excess of expense over income of $2342.63, whereas actually there was an excess of income over expense for the first three months in the fiscal year of $1243.85.

War Standardization Activities

It was voted to authorize and direct the Outline of Work Committee to prepare a short-time procedure for the preparation and issuance of standards and recommended practices—war series—by the SOCIETY, or for the preparation and issuance of these standards and recommended practices for the Government Bureaus, and further, to direct the Outline of Work Committee to submit such procedure to the Executive Committee for approval by letter ballot.

Addition to Personnel of Committee on Awards

Mr. K. V. King of the Standard Oil Company of California, was appointed a member of the Committee on Awards for a term of three years commencing October 1941.

STANDARD METHODS FOR MECHANICAL TESTING OF WELDS

A revision of the bulletin *Standard Methods for Mechanical Testing of Welds* was approved by the Board of Directors of the SOCIETY on February 19, 1942, and is now available in pamphlet form. It was prepared by the Committee on Standard Tests for Welds. The original version of this bulletin was published as tentative in January 1940, and reprinted in the March 1940 issue of THE WELDING JOURNAL.

The present *Standard Methods for Mechanical Testing of Welds* embodies a

Reactor Lock and Heat Selector

This feature is used to securely lock the Reactor Rotor in any position against the fibre locking ring, when selecting the desired heat. Sufficient pressure is exerted to hold the Rotor firmly at this heat whenever locked.

All Flexible Cables

All connecting cables are made of fine-stranded copper wire covered with specially treated asbestos to give utmost flexibility and wearing qualities.

Fibre Stops and Locking Ring

The Fibre stops and locking Ring are constructed of a bone-hard gray composition, selected because of its non-magnetic qualities and resistance to pressure.

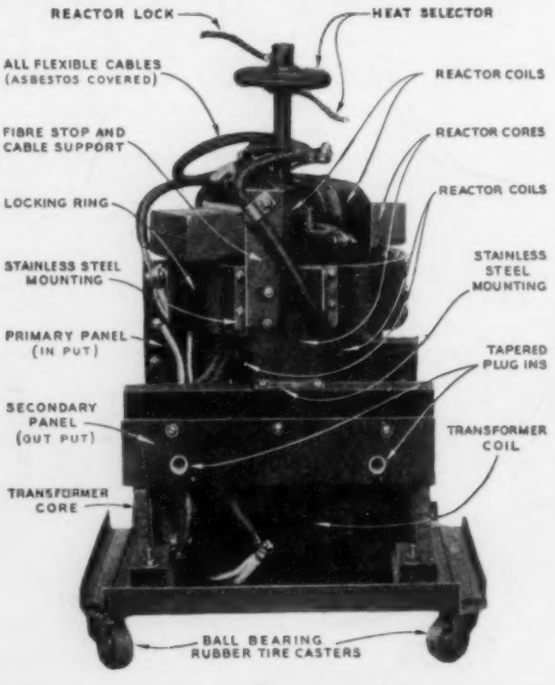
Mountings

Stainless steel, due to its low hysteresis, is used for all core mountings. It reduces eddy currents, thereby eliminating unnecessary heating at these points.

Primary and Secondary Panels

Both primary and secondary panels are built from canvas base phenolite, a highly insulating and moisture resistant material.

The Inside Story
OF THE
DIALARC A. C. WELDER



Reactor and Transformer Cores

Reactor and transformer cores are built-up of special electric steel, made exclusively for electrical use.

Reactor and Transformer Coils

All coils are wound of square copper wire covered with Class A insulation. The shape and size of the coils were pre-determined so as to properly dissipate heat without the need of artificial ventilation. Primary and secondary coils of the transformer are insulated with a sandwich of fish-paper and sheet mica. Each coil is heated to drive out atmospheric moisture, soaked in a phenolic varnish, and then baked until cured throughout.

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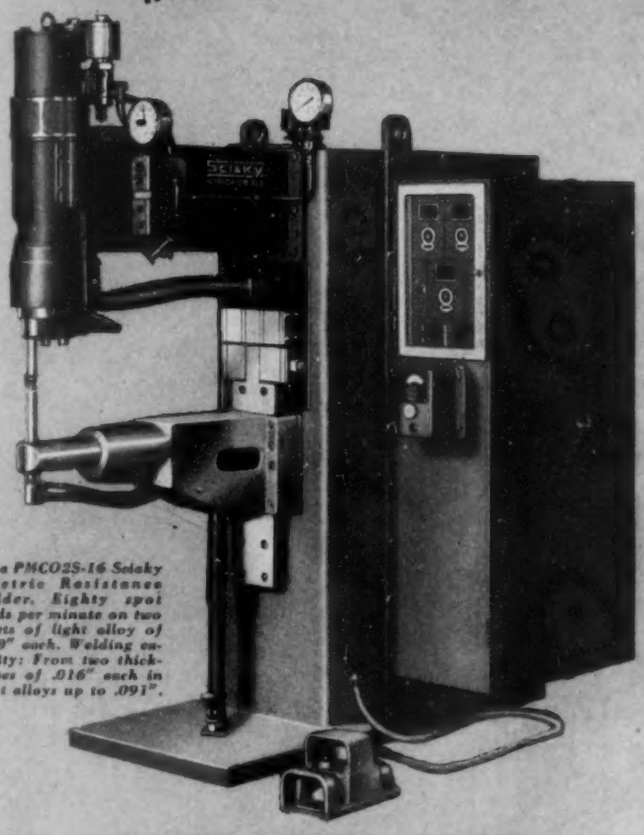
SCIAKY

(PRONOUNCED SEE-ACK-EE)

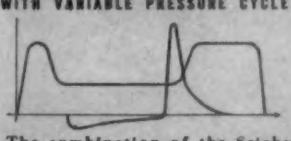
ELECTRIC RESISTANCE WELDERS

A NAME NEW TO AMERICAN INDUSTRY PROUDLY TAKES ITS PLACE WITH THE LEADERS IN THE BATTLE OF PRODUCTION FOR VICTORY



Type PMCO2S-16 Sciaky Electric Resistance Welder. Eighty spot welds per minute on two sheets of light alloy of .040" each. Welding capacity: From two thicknesses of .016" each in light alloys up to .091".

SCIAKY STORED ENERGY PRINCIPLE WITH VARIABLE PRESSURE CYCLE



The combination of the Sciaky Stored Energy Principle and the Variable Pressure Cycle produces sound, uniform welds in aluminum and other alloys at high speed with low current consumption.

YESTERDAY...

Just two short years ago, after 16 years of development work, Sciaky introduced to America the Stored Energy Principle and Variable Pressure Cycle for spot welding of aluminum alloys. These two innovations have contributed more to the advancement of large scale production of spot welding in the aircraft industry than any other factors.

TODAY...

After brief but convincing demonstration proving its many advantages, and fully satisfying army and navy authorities, the Sciaky resistance welding process is enthusiastically accepted by leading aircraft manufacturers. More Sciaky machines are now used for spot welding aluminum alloys than all other makes combined.

TOMORROW...

Re-designing of products to take full advantage of the extraordinary economies and efficiency of the Sciaky resistance welding process will result in cheaper, lighter and better airplanes, automobiles, railway cars, household utilities, and scores of other products.

This announcement is not to be construed as a solicitation for inquiries by manufacturers of civilian products. Our entire capacity production is booked for many months in advance to supply manufacturers of military aircraft and other war material producers.

SCIAKY BROS.

Manufacturers of a Complete Line of A.C. and D.C. Electric Resistance Welding Machines

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CHRYSLER CORP.
CONSOLIDATED AIRCRAFT CORP.
CURTISS-WRIGHT CORP.
DOUGLAS AIRCRAFT CO., INC.
FAIRCHILD ENGINE & AIRPLANE CORPORATION
FORD MOTOR CO.
GENERAL AIRCRAFT EQUIPMENT CORPORATION
GOODYEAR AIRCRAFT CORP.
GRUMMAN AIRCRAFT ENG. CORP.
HUGHES AIRCRAFT CO.
LOCKHEED AIRCRAFT CORP.
THE GLENN L. MARTIN CO.
NATIONAL STEEL CAR CO.
NEW YORK SHIP BUILDING CORP.
NOORDUYN AVIATION, LTD.
NORTH AMERICAN AVIATION, INC.
PULLMAN STANDARD CAR MFG. CO.
RYAN AERONAUTICAL CO.
UNITED AIRCRAFT CORP
UNITED STATES ARMY
UNITED STATES NAVY
VULTEE AIRCRAFT, INC.

number of changes from the original, most of which, however, were designed simply to improve and clarify the document without changing the principles or details of the tests.

Copies of this bulletin may be obtained from the AMERICAN WELDING SOCIETY, 33 West 39th Street, New York, N. Y., for 40¢ a copy.

WELDING HEADQUARTERS

The American Welding Society, which for a number of years had offices on the 16th floor of the Engineering Societies Bldg., 33 W. 39th St., New York, N. Y., has now moved to more spacious quarters on the 6th floor of the same building. Members of the Society are invited to visit the headquarters and look over their new offices.

NEW SUSTAINING MEMBER

Fisher Body Division, General Motors Corp., Detroit, Michigan

Few companies in the entire country do more welding than Fisher Body, which has taken a sustaining membership in the AMERICAN WELDING SOCIETY. In peace times this division of General Motors built millions of automobile bodies each year, requiring a vast amount of spot and arc welding. Fisher Body now is engaged in production of an enormous variety of armament work. These war goods Fisher Body is producing require a tremendous variety of welding work so Fisher, perhaps more than ever, is one of this nation's foremost users of welding methods. Tanks which Fisher Body is building will be, for instance, all-welded land battle-wagons.

In addition to its AMERICAN WELDING SOCIETY membership, Fisher Body has subscribed to the Research Fund of the Welding Research Committee of the Engineering Foundation, sponsored by the AMERICAN WELDING SOCIETY and the American Institute of Electrical Engineering.

OBITUARY

Arthur S. Douglass

Arthur Sylvester Douglass, Construction Engineer of The Detroit Edison Company since 1920, died on March 6, 1942, after an illness of several weeks. He was 59 years old. Mr. Douglass is survived by his widow, the former Clara Armistead; three sons, Arthur, Jr., William A. and Andrew D.; and two sisters, Josephine Douglass and Mrs. Edgar Schindler.

Mr. Douglass was born on January 16, 1883, in Plymouth, Mass. He attended Wesleyan University and received a degree in civil engineering from Massachusetts Institute of Technology in 1908. Before coming to Detroit in 1920, he had been engaged in construction work in various parts of this country and abroad.

During the first World War, Mr. Douglass was commissioned a Captain, later rose to Lieutenant Colonel in the Ordnance Department, U. S. Army. He acted as Chief of the Boston Ordnance District and received a special letter of commendation for his services.

As Construction Engineer of The Detroit Edison Company, Mr. Douglass was in responsible charge of the Construction and Drafting and Surveying Bureaus. Under his direction many of the Company's power plants, substations and other structures were built.

He was well known in Detroit for his work with the Detroit Building Congress, Committee for Trade Recovery and the Detroit City Plan Commission. He took an active part in the establishment of the City's zoning ordinance. His engineering affiliations included the Engineering Society of Detroit, of which he was a past-president; Michigan Engineering Society; American Society of Civil Engineers; Society of American Military Engineers; American Concrete Institute, of which he was a Director; and the AMERICAN WELDING SOCIETY. In the latter SOCIETY, he was a past Vice-President and a member of its Welding Research Committee.

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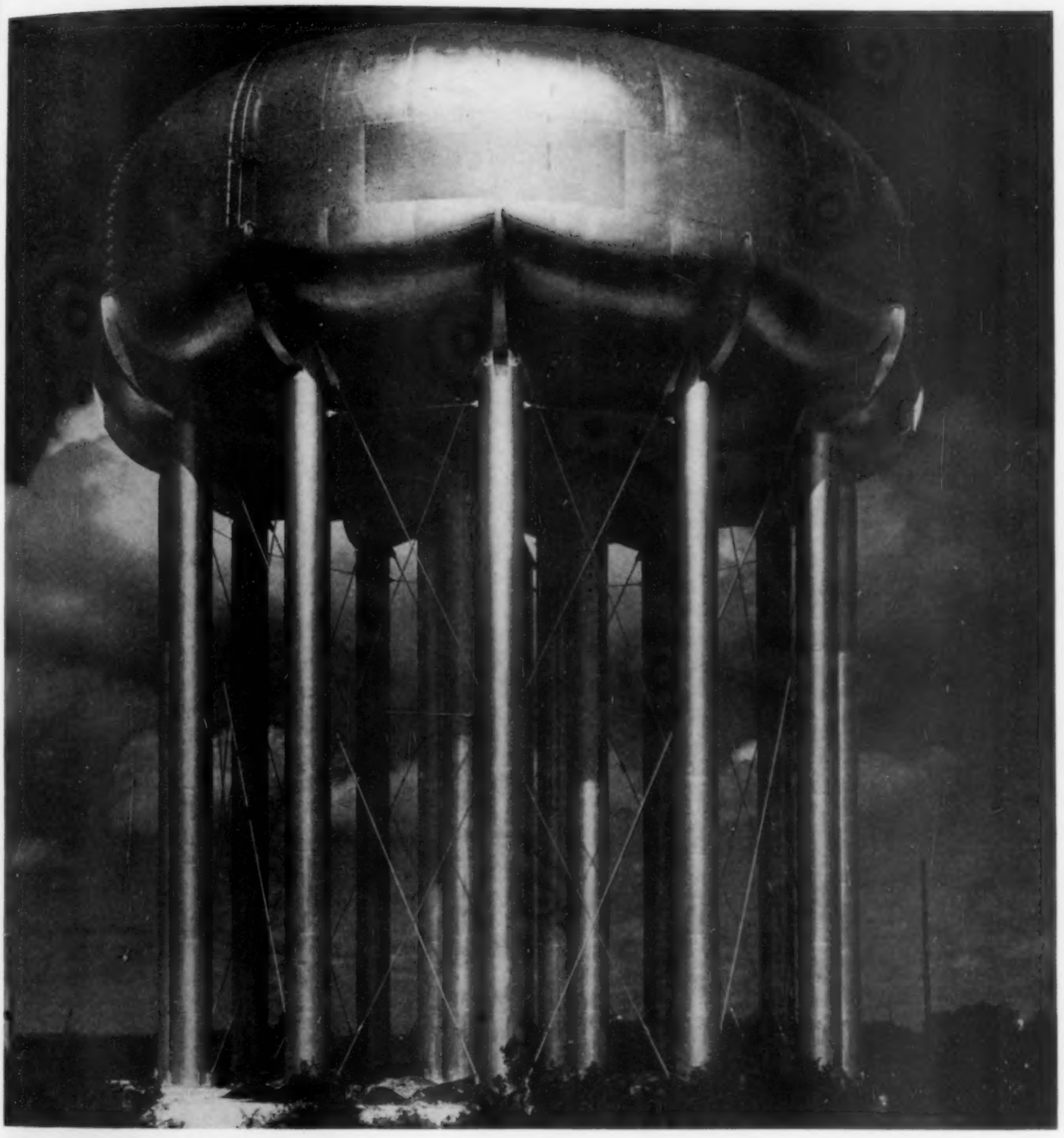

WATER TANKS

....of welded construction

The use of welded construction on large elevated water tanks, like this 1,500,000-gal. structure at San Antonio, Tex., has several distinct advantages. It simplifies the construction of the bottom girders and eliminates overlapping plates at the joints, both of which reduce the amount of metal required.

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ROBERT D. WILLIAMS

Robert D. Williams has been named a research engineer on the technical staff of Battelle Memorial Institute, Columbus, Ohio, where he will assist in the Institute's welding research.

Prior to joining Battelle, Mr. Williams was a member of the faculty in the department of Mechanical Engineering at the University of Illinois. There his work was in welding and welding metallurgy.

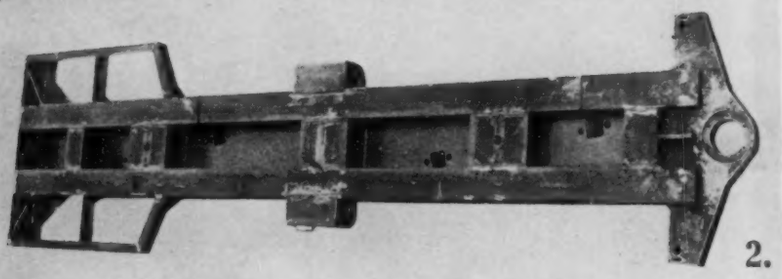
Mr. Williams is a graduate of Harvard University and of Massachusetts Institute of Technology. He is a member of the American Institute of Mining and Metallurgical Engineers and the AMERICAN WELDING SOCIETY.

ELECTRIC FREIGHT LOCOMOTIVE

Welding played an important part in the manufacture of a new electric freight locomotive recently delivered to the Piedmont & Northern Railway by the General Electric Company. The locomotive is of the 8-axle 4-truck type, with a total weight, all on drivers, of 236,000 lb. Individual axle loading is maintained at less than 35,000 lb. The 1500-v. locomotive can handle 1800-ton trailing loads.

All-welded construction was employed throughout the cab, subframing, and truck structures. Articulated subframes with the cab-structure and underframe independent of but resting on the subframes were required since there are four non-articulated 2-axle trucks. The locomotive is designed to negotiate curves with a minimum of 150-ft. radius.

1.



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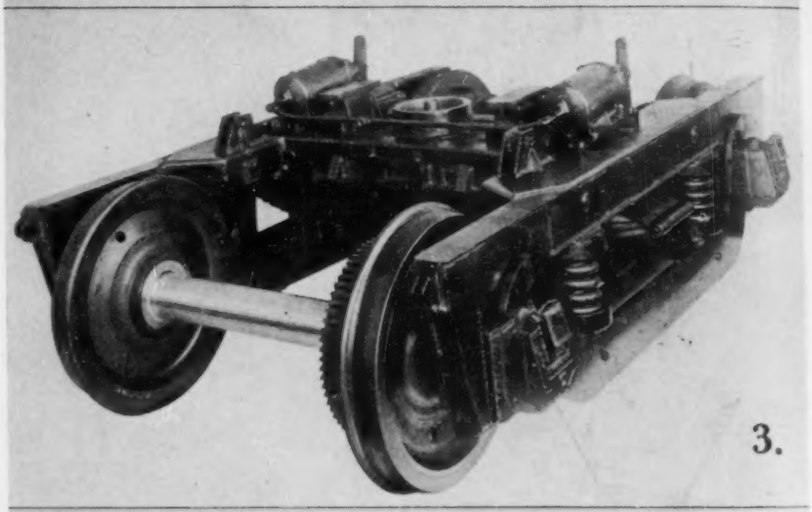

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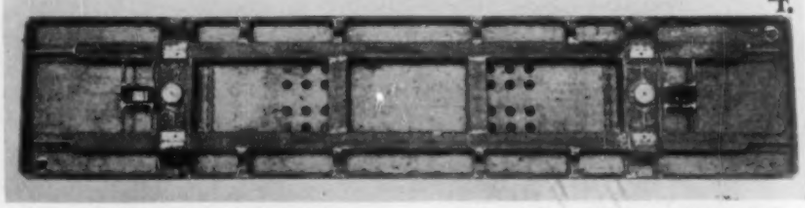

Fig. 1—1500-V. Electric Freight Locomotive for the Piedmont & Northern Railway

Fig. 2—Fabricated Subplatform, Showing Welded Construction Before Top Plate Is in Place

Fig. 3—View Showing Welded Construction of Locomotive Truck

Fig. 4—View of Welded Underframe of P & N Locomotive

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SEE HOW BRONZE WELDING SPEEDS VITAL PRODUCTION...

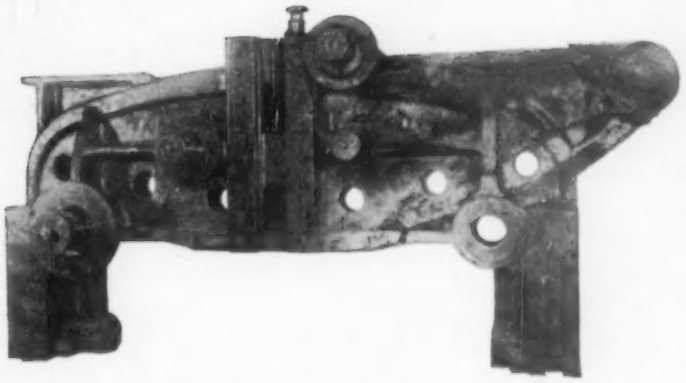
Four hundred pounds of *Anaconda 997 (low-fuming) welding rod put this crippled press back to work in just 119 man hours. To replace it would have required months, and much-needed war material would have been dangerously delayed. This job was completed by the Hebeler Welding Company, Buffalo, New York.

For information on welding with Tobin Bronze and other Anaconda rods, ask for publication B-13 . . . you'll find its data doubly useful at this time.

here

and

here



This production giant, a badly fractured 15-ton triple action press crown was back on the job in a week thanks to the Super Arc Welding Company of Detroit and 1150 pounds of *Tobin Bronze.

4295

*The trade-marks "Anaconda" and "Tobin Bronze" are registered in the U. S. Patent Office.

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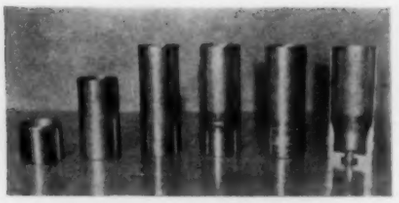


Courtesy Hobart Bros.

SMOKE SHELLS

To give the Japs a warm welcome, arc welders are at work 24 hours a day in a Canadian munitions plant producing 3-in. smoke shells. Operation is the joining of a welded steel tube to a steel forged smoke shell base.

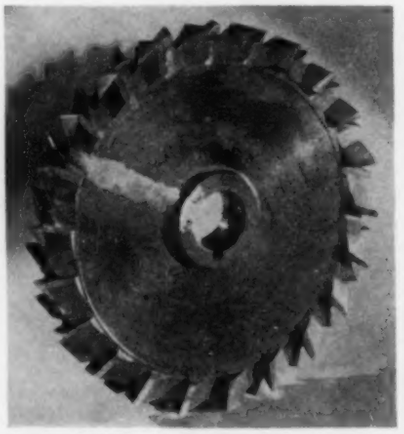
STANDARDIZATION ACTIVITIES OF NATIONAL TECHNICAL AND TRADE ORGANIZATIONS

Compiled by Robert A. Martino; issued November 28, 1941; for sale by the Superintendent of Documents, Government Printing Office, Washington, D. C. 75¢ a copy.

This volume represents an effort to present an adequate picture of the standardization and simplification movement being carried on by national technical and trade organizations in the United States. It contains outlines of the activities and accomplishments of 450 American societies and associations in which standardization is a major or an important activity. Special attention has been given to the cooperation of these organizations with the leading technical bodies whose principal activities are in the field of standardization or work directly related thereto.

HOW TO WELD A KEYWAY CUTTER

With metal working tools at a premium these days it is vitally important that broken pieces be repaired if it is at all possible to do so. A case in point at the Westinghouse East Pittsburgh works is that of a $100 keyway cutter which was repaired at a total welding cost of $25.



A 0.005-in. crack extended from keyway to base of the cutting tools. To repair, grooves were extended on both sides of the cutter and ground 1/8 in. The radius of the groove at the bottom was 10°. The cutter was preheated to 800° F. and welded with 18–8 stainless steel rod, 1/8 in. in diameter. The piece was reheated to 800° and allowed to cool slowly in an open end furnace. Cutter was then hardened by heating to 2300° F., followed by cooling in an air blast.

LINCOLN FOUNDATION REPORTS WIDE INTEREST IN $200,000 PROGRESS PROGRAM

Much wider interest is being shown in the present $200,000 Progress Program being sponsored by The James F. Lincoln Arc Welding Foundation than in the program of 1937–38, it was announced today by officials of the Foundation.

According to the officials, a number of papers have already been received, and the total number of requests for copies of the Rules and Regulations concerning awards has already exceeded the former program by approximately 50%.

The Progress Program which closes June 1st of this year, is expected to bring to light information which will be extremely helpful to industries engaged in the war effort.

Since the papers submitted will contain data explaining how production may be speeded up, how war products may be improved and how costs may be reduced by the use of modern arc welding, the advantages to all industry through compilation of these papers will obviously be manifold—not only in present war production,

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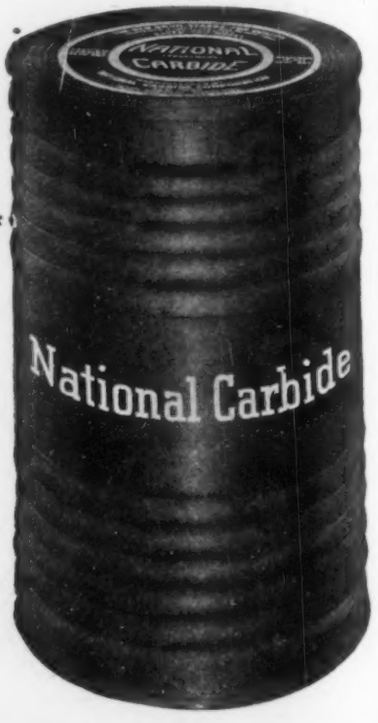

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For data on Ampco-Trode weldrods, welding technique, and applications, see our new Ampco-Trode Bulletin, sent free on request. Our welding engineers are also at your service. Consult them without obligation.

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but in the peace time production that will follow.

In support of this belief is the fact that many studies submitted in the first Foundation Award Program have become basic reference data for welding production of vital machinery and equipment, particularly in the super-speed production of ordnance items, such as gun mounts, warplanes, battleships, cruisers, destroyers, tanks and many others.

The 458 awards of the Program totaling $200,000, consist of: one each of $10,000, $7500 and $5000; 12 each of $3000, $2000, $1000 and $800; 46 each of $700, $500, $250 and $150; and 223 each of $100. The Grand Award is $13,700.

All those intending to participate in the Progress Program are reminded that their papers must be postmarked not later than June 1st to qualify for the award.

REPAIRING LAMP POST

Before. When car meets post this happens. This cast-iron street light standard at Grand Rapids, Mich., was smashed to the well-known smithereens (Fig. 1).

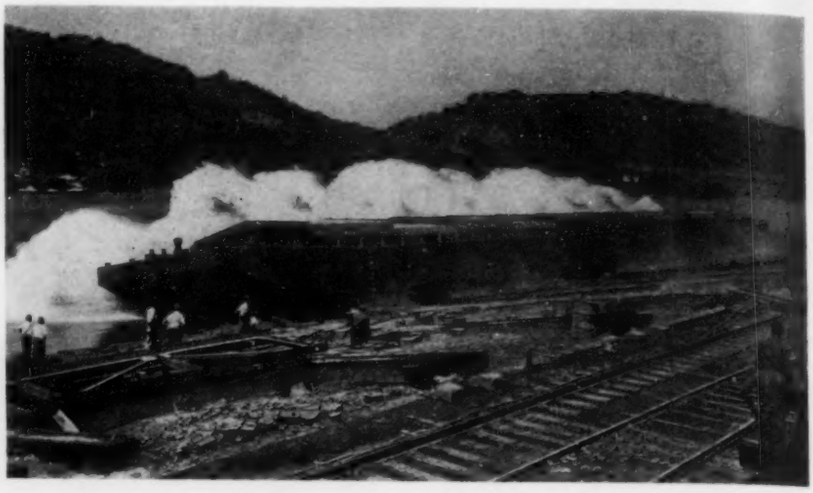
After. A neat clean repair job was made by city maintenance men at Grand Rapids. Total cost of the welding job was about one-fourth the price of a new standard (Fig. 2).

Courtesy Westinghouse Elec. & Mfg. Co.

FIFTEEN CARGO BARGES JUST OFF THE WAYS

Many interesting features characterize this new fleet of river barges constructed for the Inland Waterways Corp.

They are double-bottomed, double-sided, measuring 280 by 48 by 11 ft.—



providing a usable cargo space 236 ft. long, 37 ft. wide, with a depth of 12¼ ft. between floor level and top of the 2¼-ft. coaming. Their cargo capacity is rated at 2806 net tons on a 9-ft. draught. Of all-welded construction, they are built to the American Bureau of Shipping A-1 Classification for River Service.

Special construction features include 4 oil-tight compartments at each peak, beyond cargo space, while 24 additional water-tight compartments are built into the double sides, bottom and cargo space. Provision is also made for the separate pumping and draining of each of the 32 compartments.

Complete cargo protection is provided by eleven rolling hatch covers, ingeniously designed to telescope, permitting the desired flexibility in arrangement of openings for cargo stowage. Five alternate 20-ft. full-width openings are available for this purpose.

WAR PRODUCTION BOARD

Production Division

Mass production of a new medium tank for the Army has begun at a new Midwestern plant, William H. Harrison, Director of the Production Division of the War Production Board, announced recently.

Known as the M-4 medium tank, it is the forerunner of thousands of similar design that will be built this year as part of the program for 45,000 tanks set by President Roosevelt as the goal for 1942.

Other plants now turning out M-3 medium tanks shortly will begin making the M-4. In changing from one model to the other, there will be a minimum of lost productive time. Some plants will begin building M-4's while finishing the last of their orders for M-3's and will have two models leaving production lines at the same time. In other plants, extensive plans are being made so the first of the new type tank will follow immediately after the last of the old type tank.

As other new tank arsenals come into production, they will begin with the M-4 medium models. Dates originally set for delivery of the first tanks from these new sources have been advanced considerably in order to meet the President's requirements. It is expected that several more tank plants will be in mass production in the near future.

The new medium tank will use cast steel and welded hulls to a much greater extent than the M-3 and a change in design will increase the effectiveness of its armament.

Meanwhile, additional plants are being made ready to build light tanks to augment those that now are producing this type of combat vehicle. Plans currently call for several new types of light tanks and they will come into production when facilities now being prepared are ready.

When the tank program gets in full swing it will be drawing its heaviest support from the locomotive, automotive and farm machinery industries.

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WAR SPECIFICATIONS

Changes in steel specifications to further the production drive and thus meet the demands of the war effort were announced today by the War Production Board.

The changes are designed to conserve the supplies of steel alloys, the vital materials that make the hard, tough steel modern warfare demands.

The most important material used in modern war is alloy steel. With the rapid increase in production, it quickly became evident that unless steel alloys were conserved, there would not be enough for both the war program and essential civilian demands.

In anticipation of this shortage, representatives of the steel industry, the Society of Automotive Engineers, the Iron and Steel Institute and other technical bodies were called together by the War Production Board to discuss National Emergency Steel Specifications.

The conservation of alloying elements in these specifications is based upon the principle that small quantities of several different alloys are more effective than large quantities of any single element.

It appears that these National Emergency Steels and certain others containing less strategic elements, or none, will soon be the only steels available. It is therefore imperative, it was explained, that industry take the necessary steps to change over as quickly as possible so as to be prepared when the supply of habitually used steels is cut off.

Table 1—Available Steels

S.A.E. or A.I.S.I. No.	C	Mn	Ni	Cr	Mo
A 4027	0.25–0.30	0.70–0.90	...	...	0.20–0.30
A 4037	0.35–0.40	0.75–1.00	...	...	0.20–0.30
A 4063	0.60–0.67	0.75–1.00	...	...	0.20–0.30
A 4068	0.64–0.72	0.75–1.00	...	...	0.20–0.30
NE 8024	0.22–0.28	1.00–1.30	...	...	0.10–0.20
NE 8124	0.22–0.28	1.30–1.60	...	...	0.25–0.35
NE 8233	0.30–0.36	1.30–1.60	...	...	0.10–0.20
NE 8245	0.42–0.49	1.30–1.60	...	...	0.10–0.20
NE 8339	0.35–0.42	1.30–1.60	...	...	0.20–0.30
NE 8442	0.38–0.45	1.30–1.60	...	...	0.30–0.40
NE 8447	0.43–0.50	1.30–1.60	...	...	0.30–0.40
NE 8547	0.43–0.50	1.30–1.60	...	...	0.40–0.60
NE 8620	0.18–0.23	0.70–0.95	0.40–0.60	0.40–0.60	0.15–0.25
NE 8630	0.27–0.33	0.70–0.95	0.40–0.60	0.40–0.60	0.15–0.25
NE 8724	0.22–0.28	0.70–0.95	0.40–0.60	0.40–0.60	0.20–0.30
NE 8739	0.35–0.42	0.75–1.00	0.40–0.60	0.40–0.60	0.20–0.30
NE 8744	0.40–0.47	0.75–1.00	0.40–0.60	0.40–0.60	0.20–0.30
NE 8749	0.45–0.52	0.75–1.00	0.40–0.60	0.40–0.60	0.20–0.30
NE 8817	0.15–0.20	0.70–0.95	0.40–0.60	0.40–0.60	0.30–0.40
NE 8949	0.45–0.52	1.00–1.30	0.40–0.60	0.40–0.60	0.30–0.40

All of the above steels contain 0.20–0.35 silicon and .040 maximum each sulphur and phosphorus.
In addition to the above, the usual plain carbon (1000 series), high sulphur (1100 series), high phosphorus (1200 series), silicomanganese (9200 series) steels are available in the various carbon ranges, as are, also, certain other carbon molybdenum (4000 series) steels.

Steels containing the strategic elements nickel, chromium, tungsten, cobalt and vanadium may only be used on extremely important functional parts. Hence, industry is urged to use carbon and intermediate manganese steels (1000–1100–1200 series), carbon molybdenum (4000 series), manganese molybdenum (8000–8100–8200–8300–8400–8500 series) or silico manganese (9200 series) wherever possible.

The analyses of the alternate steels which will be available are given in Table 1, attached. Existing steel specifications with the National Emergency equivalents are given in Table 2.

Those interested in obtaining these steels can apply to their regular steel sources. Heats have already been made by a number of companies, including the following: Bethlehem Steel Corp., Carnegie-Illinois Steel Co., Copperweld Steel Co., Pittsburgh Crucible Steel Co., Republic Steel Corp., Rotary Electric Steel Co., Timken Steel and Tube Co. and Youngstown Sheet and Tube Co.

In the early stages of this program it may not be possible for a user to obtain the exact bar size or shape to which he is accustomed and it may be necessary to accept some other size and possibly even a

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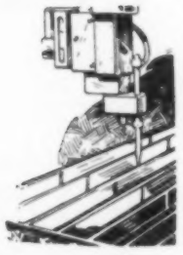

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Photo Philip Gendreau, N. Y.
Army tank welded with stainless steel electrodes.

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Sales Office—1600 Summer Street, Philadelphia, Pa.

forged bar in order to carry out a test program.

Test steel should be ordered in the usual manner.

Table 2—Steel Specifications

Standard Series Designation				Possible Alternates S.A.E. or A.I.S.I. No.		
1942 A.I.S.I. No.	1941 A.I.S.I. No.	1942 S.A.E. No.	1941 S.A.E. No.	No.	No.	No.
A 1320	A 1321	1320	..	A 4027	NE 8024	
A 1330	A 1330	1330	1330	A 4037	NE 8233	
A 1340	A 1340	1340	1340	A 4047	NE 8245	
A 2317	A 2317	2317	2315	A 4027	NE 8024	NE 8620
A 2330	A 2330	2330	2330	A 4037	NE 8233	NE 8630
A 2335	A 2335	..	..	A 4063	NE 8339	NE 8739
A 2340	A 2340	2340	2340	A 4068	NE 8442	NE 8744
A 2345	..	2345	2345	A 4068	NE 8447	NE 8749
WD 2350	..	..	..	A 4068	NE 8547	NE 8949
A 2515	A 2514	2515	2515	A 4027	NE 8817	
A 3045	A 3045	..	..	A 4068	NE 8442	NE 8744
A 3120	A 3120	3120	3120	A 4027	NE 8024	NE 8620
A 3130	A 3130	3130	3130	A 4037	NE 8233	NE 8630
A 3135	A 3135	3135	3135	A 4063	NE 8339	NE 8739
A 3140	A 3140	3140	3140	A 4068	NE 8442	NE 8744
A 3141	A 3141	3141	X 3140	A 4068	NE 8447	NE 8749
A 3145	A 3145	3145	3145	A 4068	NE 8447	NE 8749
A 3150	A 3150	3150	3150	A 4068	NE 8547	NE 8949
A 3240	A 3240	3240	3240	A 4068	NE 8442	NE 8744
WD 3250	..	..	..	A 4068	NE 8547	NE 8949
A 4119	A 4119	4119	..	A 4027	NE 8024	
A 4130	A 4130	4130	X 4130	A 4037	NE 8233	NE 8630
A 4137	A 4137	4137	..	A 4063	NE 8339	NE 8739
A 4142	A 4142	..	..	A 4063	NE 8442	NE 8744
A 4145	..	4145	..	A 4068	NE 8447	NE 8749
A 4150	..	4150	4150	A 4068	NE 8547	NE 8949
A 4320	A 4320	4320	4320	..	NE 8124	NE 8724
A 4340	..	4340	X 4340	A 4068	NE 8547	NE 8949
A 4620	A 4620	4620	4620	A 4027	NE 8024	NE 8620
A 4640	..	4640	4640	A 4063	NE 8339	NE 8739
A 4645	..	..	..	A 4068	NE 8447	NE 8744
4650	..	..	..	A 4068	NE 8547	NE 8949
A 4820	A 4821	4820	4820	..	NE 8124	NE 8724
A 5045	A 5045	..	..	A 4063	NE 8339	
A 5120	A 5120	5120	5120	A 4027	NE 8024	
A 5130	A 5130	..	..	A 4037	NE 8233	
A 5140	..	5140	5140	A 4063	NE 8339	
A 5145	A 5145	..	..	A 4068	NE 8442	
A 5150	A 5152	5150	5150	A 4068	NE 8447	
A 6120	A 6120	..	..	A 4027	8024	NE 8620
.. ..	..	6130	..	A 4037	NE 8233	NE 8630
WD 6140	..	..	..	A 4063	NE 8339	NE 8739
A 6145	..	..	..	A 4068	NE 8442	NE 8744
A 6150	..	6150	6150	A 4068	NE 8447	NE 8749

Employment Service Bulletin

SERVICES AVAILABLE

A-432. Electric welder and burner. Two years' experience in iron shop working on metals from 10 gage to 1/4 in. thick. Vertical and overhead positions. Would like opportunity in shop where ambitious person can advance himself.

A-433. Mechanical Engineer. Specialized in metallurgy, welding and heat treating. B.S. and M.S. degrees. Seven years' teaching and research in a leading university; fourteen years' industrial experience in production, supervision and control. Age 38, married, two dependents.

POSITIONS VACANT

V-113. Welding Engineer for design work, calculation of stresses for welded structures, estimating of costs for welded design in lieu of other forms of construction on steel buildings, bridges, pipe line systems and industrial products.

V-114. Welding Supervisor for work on welding on buildings, bridges, pipe line systems (oil, gas, water and pressure systems, both exterior and interior systems) and industrial products. If applicant has been in supervisory work in welding on work other than shown above please so state.

V-115. Welding operator, electric and oxyacetylene. Please state if qualified for one or both and whether qualified in all positions such as flat, vertical and overhead. State type of work in which you have received experience and the time spent in that particular work. If you have had experience in welding other types of metals in the non-ferrous field please so state.

MOTION PICTURES ON "THE INSIDE OF ARC WELDING"

Six one-reel, all-color sound motion pictures designed to help speed war efforts through the faster and better training of welding operators are now under way for the General Electric Company, according to an announcement by C. I. MacGuffie, manager of G-E arc-welding sales. Titled "The Inside of Arc Welding," the films are being produced by the Raphael G. Wolff Studios, Hollywood, who have evolved a new technique for picturing this difficult subject in a dramatized and highly interesting manner.

When completed the pictures will be made available to public, private and industrial welding schools, as well as to other interested groups. The first of the pictures covers the fundamentals of arc welding. It is scheduled for general release about April 20th.

The other pictures will be available about June 1st, and will deal with technique of arc control and electrode manipulation for all welding positions, using both d.c. and a.c. equipment.

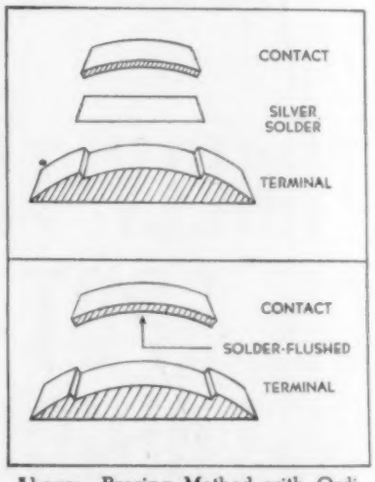
Because they will show for the first time just what actually goes on inside the arc, the "Inside Arc Welding" pictures will be of great interest to the expert welder as well as the beginner. Through the application of new methods of lighting, the all-color pictures will show the electric arc in operation, revealing details of the arc and crater impossible to photograph previously.

Ingenious animated cartoons and actual welding shots will be combined to add punch to the treatment of the subject. Featured in the cartoons will be "Joe Magee, the Welder," a timid, but likable character created by Hollywood, especially for the job.

Information as to how to obtain the pictures will be supplied by the Visual Instruction Section, Publicity Department, General Electric Company, Schenectady, N. Y., or the nearest General Electric office or arc-welding distributor.

SILVER BRAZED CONTACTS

Substantial savings in production time when making electrical contact assemblies are made possible by the use of solder-flushed contacts supplied by the Gibson Electric Co., 8362 Frankstown Ave., Pittsburgh, Pa. In some instances, an operator can double the number of contact assemblies brazed in a given time by using solder-flushed contacts.



Above: Brazing Method with Ordinary Contact. Below: Brazing with Solder-Flushed Contacts Eliminates Need for Inserting Separate Piece of Solder

Solder-flushed contacts are contacts which have been coated on one side with silver solder so that they may be applied immediately to the terminal. The contact is simply placed on the terminal and brazed in an electric welder, eliminating the extra operation of placing a separate piece of solder between the contact and the terminal.

The savings in time when solder-flushed electrical contacts are used reduces production costs. Furthermore, a uniform distribution of solder in the joint between the contact and the terminal is assured. Complicated contact assemblies, which are impossible or very difficult to make when a separate piece of solder is required, are easily brazed with solder-flushed contacts.

ATTACK

PRODUCTION PROBLEMS

with

RESISTANCE WELDING

In recent months, Resistance Welding has proved to be much more than a good way to assemble metal products. It is helping to make more and better war materials by producing parts at high speed and low cost that formerly required slow and expensive casting or machining operation. It is providing a variety of ways to eliminate bolts, rivets and other fastening devices; to produce smooth, unbroken surfaces that require less preparation for finishing; to cut down weight; to increase strength; to simplify the construction of many products.

In addition, Resistance Welding is helping to keep other equipment on the job by solving repair and maintenance problems and in the conservation and re-use of hard-to-get materials.

An experienced welding engineer, representing one of the member companies listed here, can tell you quickly just what Resistance Welding can do for you. Why not call one in today?

RESISTANCE WELDER
MANUFACTURER'S ASSOCIATION
505 Arch Street **Philadelphia, Pa.**

RESISTANCE WELDER MANUFACTURERS ASSOCIATION · RWMA

MEMBER COMPANIES

Welding Machines Mfg. Company, Detroit, Mich.
Acme Electric Welder Company, Los Angeles, Calif.
American Electric Fusion Corporation, Chicago, Ill.
Eisler Engineering Company, Newark, N. J.
Expert Welding Machine Company, Detroit, Mich.
Federal Machine and Welder Company, Warren, Ohio
Multi-Hydromatic Welding and Manufacturing Co., Detroit, Mich.
National Electric Welding Machines Co., Bay City, Mich.
Progressive Welder Company, Detroit, Mich.
Swift Electric Welder Company, Detroit, Mich.
Taylor-Hall Welding Corporation, Worcester, Mass.
Taylor-Winfield Corporation, Warren, Ohio
Thomson-Gibb Electric Welding Co., Lynn, Mass

ASSOCIATE MEMBER COMPANIES

P. R. Mallory and Co., Indianapolis, Ind.
S-M-S Corporation, Detroit, Mich.
Electroloy, Inc., New York, N. Y.
Welding Sales and Engineering Co., Detroit, Mich.

NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

WELDING REPLACES MACHINING

Development of welding gun attachments for balancing machines by Progressive Welder Company, E. Outer Drive, Detroit, has eliminated the necessity of "balance-machining" of rotating parts on which accurate dynamic balance is required—also making unnecessary leaving of excess stock on parts for this purpose. Two such attachments are shown here.

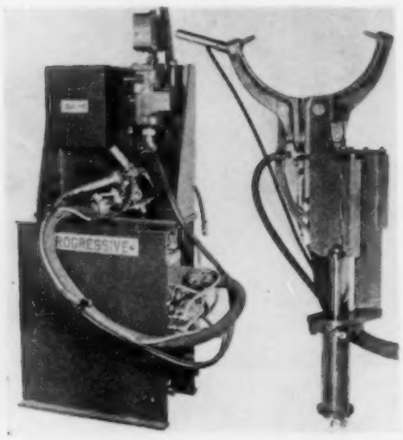


Fig. 1

Fig. 2

The gun in Fig. 1 is fitted with a bracket which hooks over the ring gear of a hydraulic coupling. The gun is swung over and a balancing lug of the correct weight needed is spot-welded to the housing.

The gun in Fig. 2 is semi-automatic in operation. It moves into welding position actuated by an air cylinder. Welding is indirect. An adjustment is provided for the jaw opening.

Both guns are hydraulic in operation.

SEQUENCE TIMER FOR RESISTANCE WELDING

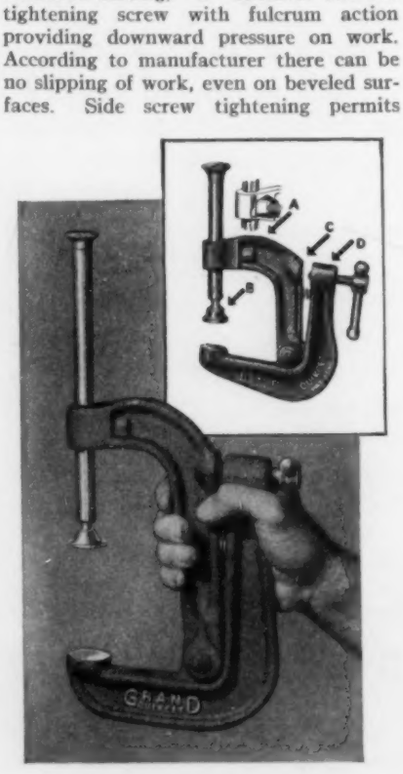
For use in automatic resistance spot, butt or projection welding, a new weld and sequence timer is announced by Westinghouse Elec. and Mfg. Co.

The timing circuit is fully electronic and consists essentially of a resistor capacitor circuit whose charging rate is adjustable by varying a resistor. The voltage of the circuit is applied to the grid of a thyratron tube so that after a predetermining charging time has elapsed, the thyratron is energized and operates the relay.

The timer divides the total time of a weld into the various intervals in which the welder goes through its operating sequence and includes a "weld" period of 3 to 30 cycles when the full welding current flows. When welding thick plates, brass or stainless steel, timing facilities permit intermittent heating and cooling steps of from 3 to 30 cycles.

CLAMP

New in principle and timely in application because of increased use in defense production, is this fulcrum leverage speed clamp called QUIKCET, just put on the market by the Grand Specialties Co., Chicago, Ill. Four second clamping and one hand operation is claimed through setting with ratchet rod instead of turn screw. "A" is spring activated pawl for ratchet. "B" is replaceable swivel. Case hardened casting, "C" contacts vise-like tightening screw with fulcrum action providing downward pressure on work. According to manufacturer there can be no slipping of work, even on beveled surfaces. Side screw tightening permits clamping in close quarters and also quick release. Rod and screw are copper plated and "V" shoes may be furnished for pipe and rod holding.

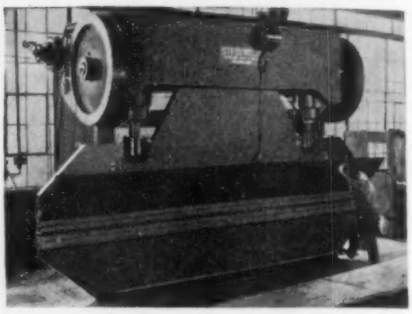


BENDING PRESS

The Steelweld Machinery Division of The Cleveland Crane & Engineering Company, Wickliffe, Ohio, announce a new Steelweld Bending Press, Model L5$^{1}/_{2}$-12, with double bed and ram extension for bending and forming plate up to 20 ft. in width.

Various plate thicknesses may be handled, depending upon the plate width. The picture shows a 20-ft. plate $^{5}/_{16}$ in. being bent. The same machine will bend $^{1}/_{2}$-in. plate up to 12 ft. in width, and even heavier plate that is less in width.

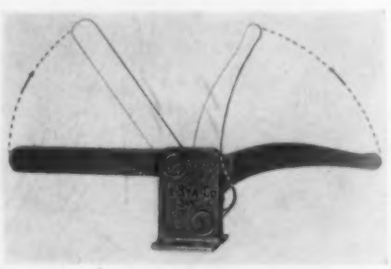
Like all presses in the Steelweld line, the frame is of the one-piece all-welded steel construction and will remain rigid for life.



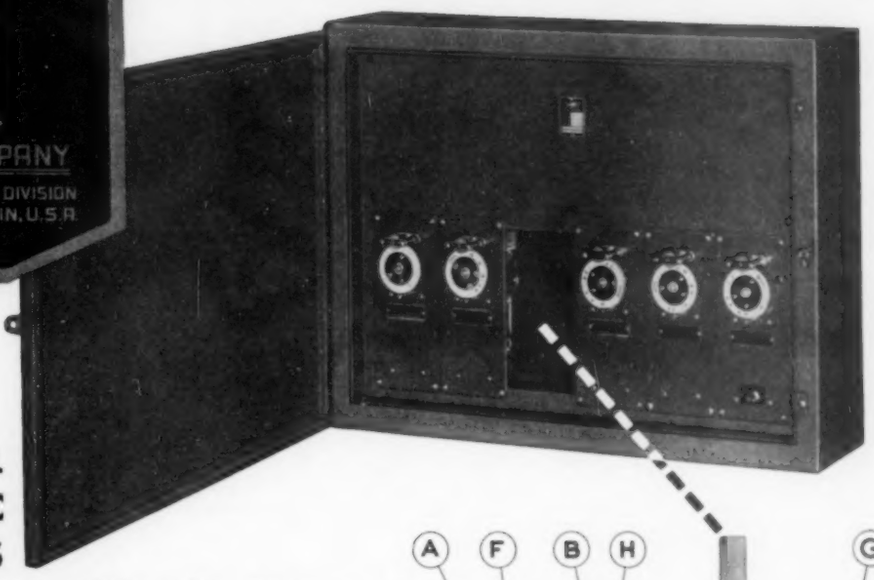
Bending, forming, blanking, drawing and multiple-punching operations may be performed on Steelweld presses. Gages and indicators provided make it a simple matter to obtain identical results repeatedly with a set of dies.

LIGHT DUTY TOGGLE CLAMP

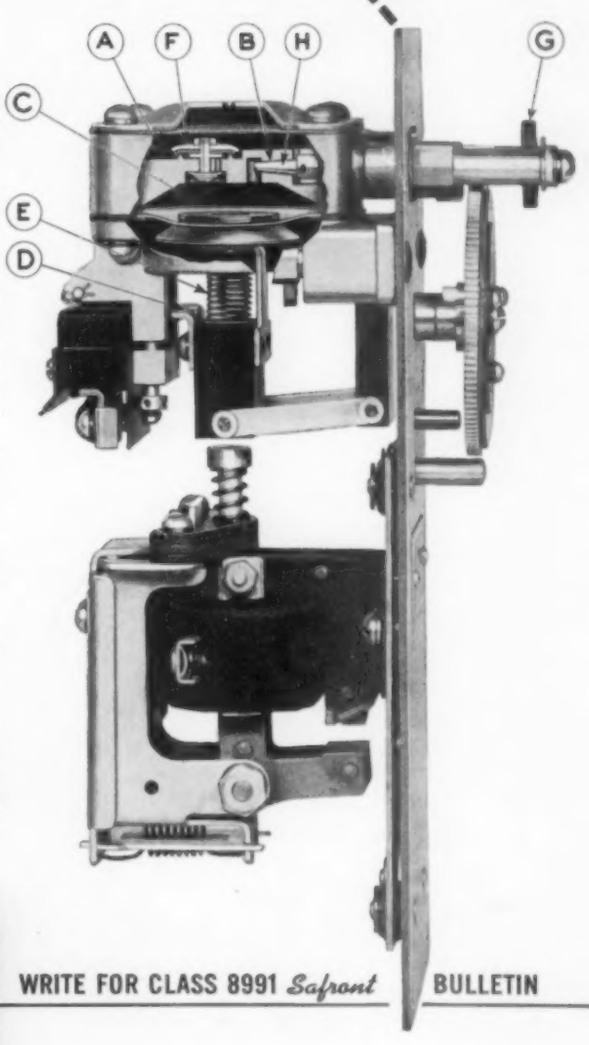
New light duty, horizontal style toggle clamp has been added to the De-Sta-Co line of clamps manufactured by the Detroit Stamping Company, Detroit, Mich. This new clamp has a pressure ratio of 50 to 1. When in "shut" position (as illustrated) both the handle and clamping bar are in a horizontal position, thus reducing height. Measurements are 8$^{11}/_{16}$ in. across, 2$^{3}/_{16}$ in. high over-all and 1$^{3}/_{8}$ x 2$^{1}/_{16}$ in. at the base. Illustration indicates movement of handle and clamping bar when clamp is being released to "open" position. Weight 8$^{1}/_{2}$ oz.



SEE HOW THIS NEW *Safront* WELDER CONTROL WELD TIMER OPERATES



INDIVIDUAL PNEUMATIC TIMING UNITS GOVERN EACH STEP IN THE RESISTANCE WELDING CYCLE



TIMER operation is based on the interval required to transfer a small volume of filtered air from chamber **(A)** through regulated orifice **(B)** to chamber **(C)** as force is applied to contact actuating member **(D)** by spring **(E)**. Check valve **(F)** permits instantaneous resetting. Turning knurled adjusting wheel **(G)** positions tapered pin **(H)** to determine amount of restriction in regulated orifice. Timing periods can thus be varied from 3 to 100 cycles of 60-cycle frequency with ± ½ cycle accuracy.

Each timer has a separate mounting plate with adjusting wheel and calibrated dial *in front,* and all current-carrying parts *in rear.* No danger of shock while timing adjustments are being made on the *Safront* unit.

Parts subject to wear are hardened and bearings are oil-less. Magnet coils can be exchanged without disturbing calibration of time-delay mechanism.

Safront Pulsation Weld Timer illustrated above has six timers controlling SQUEEZE, HEAT, COOL, WELD INTERVAL, HOLD and OFF periods, respectively. COOL period timer has been removed and enlarged to show construction. High-speed control relays used in the system are mounted on rear of protective panel which swings forward for inspection or maintenance. There are 18 NEMA standard types of Weld and Sequence Timers of similar construction.

SQUARE D COMPANY
INDUSTRIAL CONTROLLER DIVISION
4041 N. RICHARDS ST., MILWAUKEE, WIS.

WRITE FOR CLASS 8991 *Safront* BULLETIN

LIGHT WEIGHT TORCH

A new welding torch, measuring but 13 in. long and weighing less than 3/4 lb., has just been announced by Weldit Acetylene Co., Detroit. This torch has replaceable tip nut and the maker claims it to be especially suitable for sheet metal and aircraft welding work.

List of New Members

February 1 to February 28, 1942

BIRMINGHAM

Floyd, Walter M. (D), Chicago Bridge & Iron Co., 1500 N. 50th St., Birmingham, Ala.

BOSTON

Campbell, Robert S., Jr. (D), 10 Wilson Terr., Apt. 23, East Lynn, Mass.
Lerner, Hiram A. (C), 143 Main St., Cambridge, Mass.

CANADA

Gillespie, Robert J. (C), Lincoln Elec. Co. of Canada, Haymarket Sq., Hamilton, Ont., Canada.

CANTON

Hobbs, James C. (C), Union Metal & Mfg. Co., Maple Ave., Canton, Ohio.
Small, C. L. (D), 340 N. 2nd St., Coshocton, Ohio.
Wilhelm, D. M. (B), 319 Vine St., E. Liverpool, Ohio.

CHICAGO

Bast, William (C), 3247 N. Oakley St., Chicago, Ill.
Dixon, Wm. G. (C), 8542 S. Bennett, Chicago, Ill.
Foley, Russell (B), 7945 Oakleaf Ave., Chicago, Ill.
Green, Stanley (B), Sunset Ridge Rd., Glen View, Ill.
Hudson, John B. (B), Waukegan Rd., Glen View, Ill.
Iverson, Rex C. (D), 4022 No. Mozart St., Chicago, Ill.
Jankoski, Clarence (D), 1621 Wolfram St., Chicago, Ill.
Little, S. J. (C), 3318 N. Le Claire, Chicago, Ill.
McLaughlin, Carl B. (C), Carnegie-Illinois Steel Corp., 208 S. La Salle St., Rm. 1632, Chicago, Ill.
Sciaky, Maurice (B), Sciaky Bros., 11001 Cottage Grove Ave., Chicago, Ill.
Youngquist, Gordon (D), 11111 S. Forrestville, Chicago, Ill.

CINCINNATI

Christenson, N. H. (B), The Vulcan Copper & Supply Co., 120 Sycamore St., Cincinnati, Ohio.
Morris, Quincy A. (D), 3945 Holman Circle, Cincinnati, Ohio.
Shipley, David C. (D), 4207 Eileen Dr., Oakley, Cincinnati, Ohio.
Vetter, H. C. (C), The Ohio River Co., 725 W. Front St., Cincinnati, Ohio.

CLEVELAND

Golden, Frank W. (C), 29055 Barjod Rd., Willoughby, Ohio.
Jatzek, H. A. (C), Standard Oil Co. of Ohio, 2735 Broadway, 1 Wks., Cleveland, Ohio.
Loftus, Anthony (C), 375 E. 149th St., Cleveland, Ohio.
Mello, Gustav (C), 1071 Power Ave., Cleveland, Ohio.
Seufer, Frank C. (D), 11516 Moulton Ave., Cleveland, Ohio.
Williams, Russell E. (B), 13403 Blenheim Ave., Cleveland, Ohio.

COLUMBUS

Baughman, William C. (F), 222 So. Lincoln Ave., Alliance, Ohio.

DETROIT

Agren Douglas E. (F), 4832 University, Detroit, Mich.
Brock, Preston J. (C), 3000 Northwestern Ave., Detroit, Mich.
Clark, John L. (C), John Crowley Boiler Wks., 713 Adrien Ave., Jackson, Mich.
Coates, Frank (B), 17574 Monica Ave., Detroit, Mich.
Cox, James C. (B), S-M-S Corp., 1165 Harper Ave., Detroit, Mich.
Curlee, Charlie C. (D), 4154 Mayfair Ave., Dearborn, Mich.
Danse, L. A. (B), Cadillac Motor Car Div., 2860 Clark, Detroit, Mich.
Figley, Vaughan S. (C), A.C. Spark Plug Co., Flint, Mich.
Gray, Randal (C), 824 Dragoon Ave., Detroit, Mich.
Haskins, Howard B. (A), Fisher Body Division, 9-217 General Motors Bldg., Detroit, Mich.
Hinds, Spencer C. (C), A.C. Spark Plug Co., Flint, Mich.
Jones, Lowell L. (B), River Bluff, Niles, Mich.
Jorstad, Henry C. (B), Mackworth G. Rees, Inc., 626 Harper Ave., Detroit, Mich.
Lynn, Earle C. (D), 5262 Hecla, Detroit, Mich.
McIntyre, Joseph (C), 19 Ruth St., Ecorse, Mich.
Ploe, Elmer (C), 8636 Farmbrook, Detroit, Mich.
Rees, Mackworth G. (B), Mackworth G. Rees, Inc., 666 Harper Ave., Detroit, Mich.
Robinson, Karl A. (C), 5315 Kensington Rd., Detroit, Mich.
Rutledge, Richard (C), 14431 Camden Ave., Detroit, Mich.
Sullivan, E. John (B), Motors Metal Mfg. Co., 5936 Milford Ave., Detroit, Mich.
Ubbes, Frank (D), 1604 Reed Ave., Kalamazoo, Mich.
Urquhart, Glenn R. (B), 19157 Carman Ave., Detroit, Mich.
Washburn, Clark W. (D), 321 Trambly, Inkster, Mich.
White, George A. (B), The Sparks-Withington Co., Horn Div., Jackson, Mich.
Willet, Cecil J. (D), 19354 Brady, Detroit, Mich.
Willsey, Arthur B. (B), 7426 Hartwell Ave., Dearborn, Mich.
Zech, Alfred N. (C), 7354 Greenview, Detroit, Mich.

KANSAS CITY

Calder, Bruce (D), 606 Lincoln St., Topeka, Kans.
Fotie, Joseph A. (B), Dyer Welder Co., 7 E. 19th, Kansas City, Mo.
Thompson, Clarence A. (D), 1908 Ash, Independence, Mo.

LAKE SHORE

Gainey, Jack F. (D), 218 N. Cedar St., Sturgeon Bay, Wisc.
Staehly, Robert (D), 1493 Willow St., Green Bay, Wisc.

LOS ANGELES

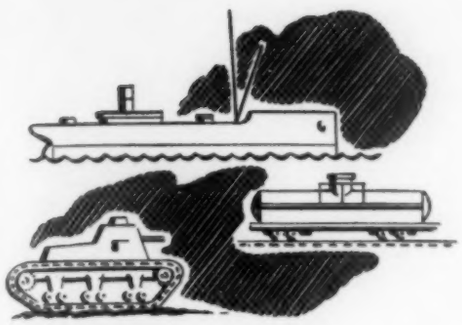
Fisher, W. P. (B), 116 S. Taylor Ave., Montbello, Calif.
Hard, Gary (C), 12527 Woodgreen St., Venice, Calif.
Higuera, William (D), 1332 W. 4th St., San Pedro, Calif.
Ohldag, Henry H. (D), Y.M.C.A., San Pedro, Calif.
Snider, W. E. (C), 994 1/2 Maple St., Inglewood, Calif.

LOUISIANA

Ammann, Werner (C), U. S. Navy, P.O. Box 511, Morgan City, La.
Lindquist, Axel S. (B), P.O. Box 393, Ville Platte, La.

MARYLAND

Freburger, Milton T., Jr. (C), 4245 Sheldon Ave., Baltimore, Md.
Hall, Stewart S. (C), 4809 Kiswick Rd., Baltimore, Md.
Lucey, T. J. (C), 1504 Pentridge Rd., Baltimore, Md.
Shaprow, Wesley H. (C), 3806 Ednor Rd. Baltimore, Md.



...Unionmelt-welded in plants like these...

to speed guns and planes and ships and tanks!

Why are plants like these—the plants turning out today's guns and ships and tanks—using Westinghouse A-C Welders and Unionmelt* Process welding?

The answer is that this happy combination helps speed up further the fastest welding process available.

Westinghouse A-C Welders, especially designed for use with Unionmelt equipment, permit butt welding plates up to ½" thick in a single pass, at speeds up to 80" per minute. And welds like these save tons of needed metal. Write for full details. Address Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., Dept. 7-N.

J-70361

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A large holder of contracts for naval and merchant marine shipping
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A large marine boiler manufacturer
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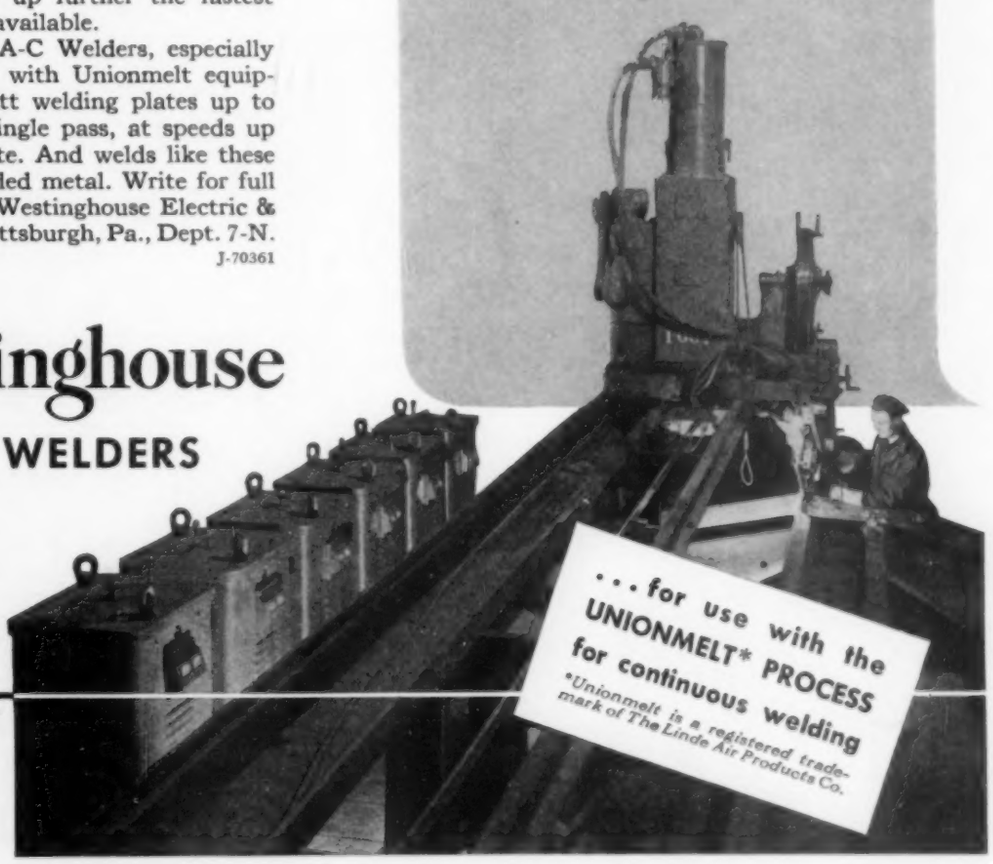
A Delaware River shipbuilder
A large New Jersey shipbuilder
A large builder of tank cars
A Mississippi shipbuilder
A Louisiana shipbuilder
A large California shipbuilder
A Chesapeake Bay builder of naval vessels
A large New Jersey holder of naval contracts
An Oregon shipbuilder
A large freight car builder
A passenger car builder
A large holder of tanker contracts
A Washington shipbuilder

Westinghouse

A-C WELDERS


. . . for use with the
UNIONMELT* PROCESS
for continuous welding
*Unionmelt is a registered trademark of The Linde Air Products Co.

MILWAUKEE

Ferderer, Geo. C. (D), 1225½ Marquette Ave., So. Milwaukee, Wisc.
Munro, A. L. (B), Smith Engrg. Wks., 532 E. Capitol Dr., Milwaukee, Wisc.

NEW YORK

Albert, Sidney G. (B), Albert Pipe Supply Co., Inc., Berry & No. 13th St., Brooklyn, N. Y.
Alleman, Cyrus E., Jr. (D), U.S.S. *Hannibal*, % Postmaster, New York, N. Y.
Angell, Robert C. (B), % The S. S. White Dental Mfg. Co., Prince Bay, N. Y.
Coby, Edward (D), 733 Prospect Ave., Bronx, N. Y.
Dabis, Clifford P. (C), 1935 E. 26th St., Brooklyn, N. Y.
Dillenbeck, Ronald B. (B), 32 Westminster Rd., Rockville Centre, L. I., N. Y.
Egan, John A. (C), 690 Henry St., Brooklyn, N. Y.
Etzold, Henry (D), 2930 Willkinson Ave., Bronx, N. Y.
Hunt, John H. (B), Combustion Engrg. Co., 200 Madison Ave., New York, N. Y.
Jensen, John H. (D), 34-34 74th St., Jackson Hgts., L. I., N. Y.
Karlson, Oscar (D), 953 Hoe Ave., Bronx, N. Y.
Lanari, Raymond (D), Texas Oil Co., Beacon, N. Y.
Liddell, Robert (D), 625 S. Broadway, Yonkers, N. Y.
Mann, John M. (D), 2991 Quenton Rd., Brooklyn, N. Y.
Mongold, Lloyd A. (C), 288 Lafayette St., Brooklyn, N. Y.
McClean, Charles A. (C), Air Reduction Sales Co., 60 E. 42nd St., New York, N. Y.
Neumann, Michel (D), 207 E. 33rd St., Apt. 4E, New York, N. Y.
Owens, Frank J. (D), 32 Linden St., Yonkers, N. Y.
Pawlik, Anthony P. (D), 685—4th Ave., Brooklyn, N. Y.
Plastaras, James C. (B), 141-40 228th St., Springfield Gardens, N. Y.
Reide, H. F. (B), 318—28th St., Union City, N. J.
Rostetter, Edward J. (B), 104 Bement Ave., W. New Brighton, Staten Island, N. Y.
Stoll, Harry (D), 804 W. 180th St., New York, N. Y.
Tantillo, Charles J. (C), Inspector of Naval Material, 30 Church St., New York, N. Y.

NORTHERN NEW JERSEY

Baker, Joseph (D), 534—9th St., Carlstad, N. J.
Burke, Donley E. (D), 32 St. Paul Ave., Newark, N. J.
Janaro, Frank (D), 121 Washington Ave., Little Ferry, N. J.
Kiel, John (D), 210 Sunset Ave., Newark, N. J.
Kete, Louis J. (C), 810 N. Broad St., Elizabeth, N. J.
Long, Dan L. (D), 1400—84th St., North Bergen, N. J.
Lukas, R. J. (D), 146 Glenwood Ave., Jersey City, N. J.
Manney, Ben (C), 324 Pennington Ave., Passaic, N. J.
Mulvale, Edward (C), Talara Club, Talara, Peru, South America.
O'Donnell, James (D), 319 Willow Ave., Lyndhurst, N. J.
Robinson, Charles F. (D), 1450 Chestnut, Hillside, N. J.
Rodin, A. George (D), 81 James St., Bloomfield, N. J.
Schnorr, Karl (C), National Grain & Yeast Co., 810 Mill St., Belleville, N. J.
Tedesco, Charles E. (D), 2 Margaret Ave., Nutley, N. J.
Tintle, De Gray (D), 141 Boonton Ave., Butler, N. J.
Vanderham, Louis (D), 93 Watson Ave., Newark, N. J.
Wiberg, William (D), 1450 Chestnut Ave., Hillside, N. J.

NORTHWEST

Stryker, C. Vernon (D), 1817—2nd Ave. So., Minneapolis, Minn.

PEORIA

Apacki, Charles (C), 725 Alexander, Peoria, Ill.
Jones, William B. (D), 106 Anderson St., E. Peoria, Ill.
Papier, Albert M. (D), 701 Jackson St., Peoria, Ill.
Watkins, Franklin (C), 2709 Gale Ave., Peoria, Ill.

PHILADELPHIA

Cohn, Garson B. (D), 5944 Addison St., Philadelphia, Pa.
Duffield, Louis (D), Michael Flynn Mfg. Co., Allegheny Ave. & Tulip St., Philadelphia, Pa.
Edgecomb, Fred J. (C), Y.M.C.A., 614 Federal St., Camden, N. J.
Lance, Paul L. (D), 704 N. Adams St., Wilmington, Del.
Laubenstein, A. R. (B), Laubenstein Mfg. Co., 422 S. 3rd St., Ashland, Pa.
Seasholtz, Paul D. (B), J. M. Seasholtz & Sons, Inc., Front & Spruce Sts., Reading, Pa.
Story, Alfred B. (C), 33 Oakland Ave., Audubon, N. J.
Walker, Kenneth M. (C), 24 Franklin Ave., Chestnut Hill, Philadelphia, Pa.

PITTSBURGH

Markey, Edward J. (C), National Annealing Box Co., Box 256, Washington, Pa.
Schuster, R. H. (C), 3329 Perrysville Ave., N. S. Pittsburgh, Pa.
Speicher, Donald E. (C), 845—17th St., Altoona, Pa.

ROCHESTER

Kane, Thomas B. (B), F. L. Heughes & Co., 1029 Lytell Ave., Rochester, N. Y.

ST. LOUIS

Klingsick, O. W. (B), Day-Brite Lighting, Inc., 5411 Bulwer Ave., St. Louis, Mo.

SAN FRANCISCO

Belles, Albert O. (C), 1106 Divisadero St., San Francisco, Calif.
Bermen, Henry (D), 321 Holly Park Circle, San Francisco, Calif.
Felger, Adolph (D), 290 Alhambra St., San Francisco, Calif.
Gray, Charles E. (D), Box 8, So. San Francisco, Calif.
Johnson, Charles A. (C), 629 Valle Vista Ave., Oakland, Calif.
Labagh, Richard E. (B), Victor Equip. Co., 844 Folsom St., San Francisco, Calif.
Nelson, Ernest (D), 733 Bay Shore Blvd., So. San Francisco, Calif.
Thorndike, Franklin R. (B), 454 No. El Camino Real, San Mateo, Calif.
Wipprecht, William (D), Box 158, Brisbane, Calif.
Woodruff, Glenn B. (B), 2709 Dwight Way, Berkeley, Calif.

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Alhart, C. G. (D), Texas Iron Wks., 1423 Maury, Houston, Tex.
Doggett, J. E. (D), 3134 Southmore Blvd., Houston, Tex.
Rackley, Clyde L. (D), 892 Broadway, Beaumont, Tex.
Sheffield, R. W. (D), 7071 Sherman St., Houston, Tex.
Smith, W. T. (B), 7035 Sidney St., Houston, Tex.

TULSA

Rickel, F. J. (B), Big Three Equip. Co., Box 910, Tulsa, Okla.
Maxwell, Arthur (D), Big Three Equip. Co., Box 910, Tulsa, Okla.

WASHINGTON, D. C.

Taylor, Woodrow L. (C), 1401—22nd St., S. E., Washington, D. C.

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Bretherton, R. (D), Bell Aircraft Corp., 2050 Elmwood, Buffalo, N. Y.
Ernst, Elmer L. (B), Ernst Iron Wks., Inc., 75 Lathrop St., Buffalo, N. Y.
Holzer, Vernon L. (D), Bell Aircraft Corp., 2050 Elmwood, Buffalo, N. Y.
Jesionowski, Richard A. (C), 66 W. Doughty St., Dunkirk, N. Y.
Patti, Frank (C), Allegheny Ludlum Steel Corp., P.O. Box 12—Sta. B, Buffalo, N. Y.

WICHITA

Burrows, Delmer (D), R.F.D. Augusta, Kans.

YORK—CENTRAL PENNA.

Bean, Willis E. (D), 215 E. King St., York, Pa.
Bech, Sherman (D), R.D. 6, York, Pa.
Christ, Lester W. (D), 1441 W. Phila. St., York, Pa.
McCulloh, William L. (D), Mercersburg, Pa.
Strobel, Frank E. (C), Penn. Boiler & Burner Mfg. Corp., Fruitville Rd., Lancaster, Pa.
Willard, William D. (D), 306 No. Hartley St., York, Pa.

YOUNGSTOWN

Mauser, Edward (D), 125 W. Princeton, Youngstown, Ohio.
Schultz, O. A. (D), R.D. 2, Hubbard, Ohio.

NOT IN SECTIONS

Davis, George L. (C), P.O. Box 546, Galveston, Tex.
Gamache, Rodolphe W. (C), 16 Thomas St., Springfield, Mass.
Graveley, Robert L. (C), P.O. Box 546, Orlando, Fla.
Gunderson, A. E. (B), Gunderson Bros., 225 N. W. 14th Ave., Portland, Ore.
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Jones, Frank A. (B), 60 Wall St., Bristol, Tenn.

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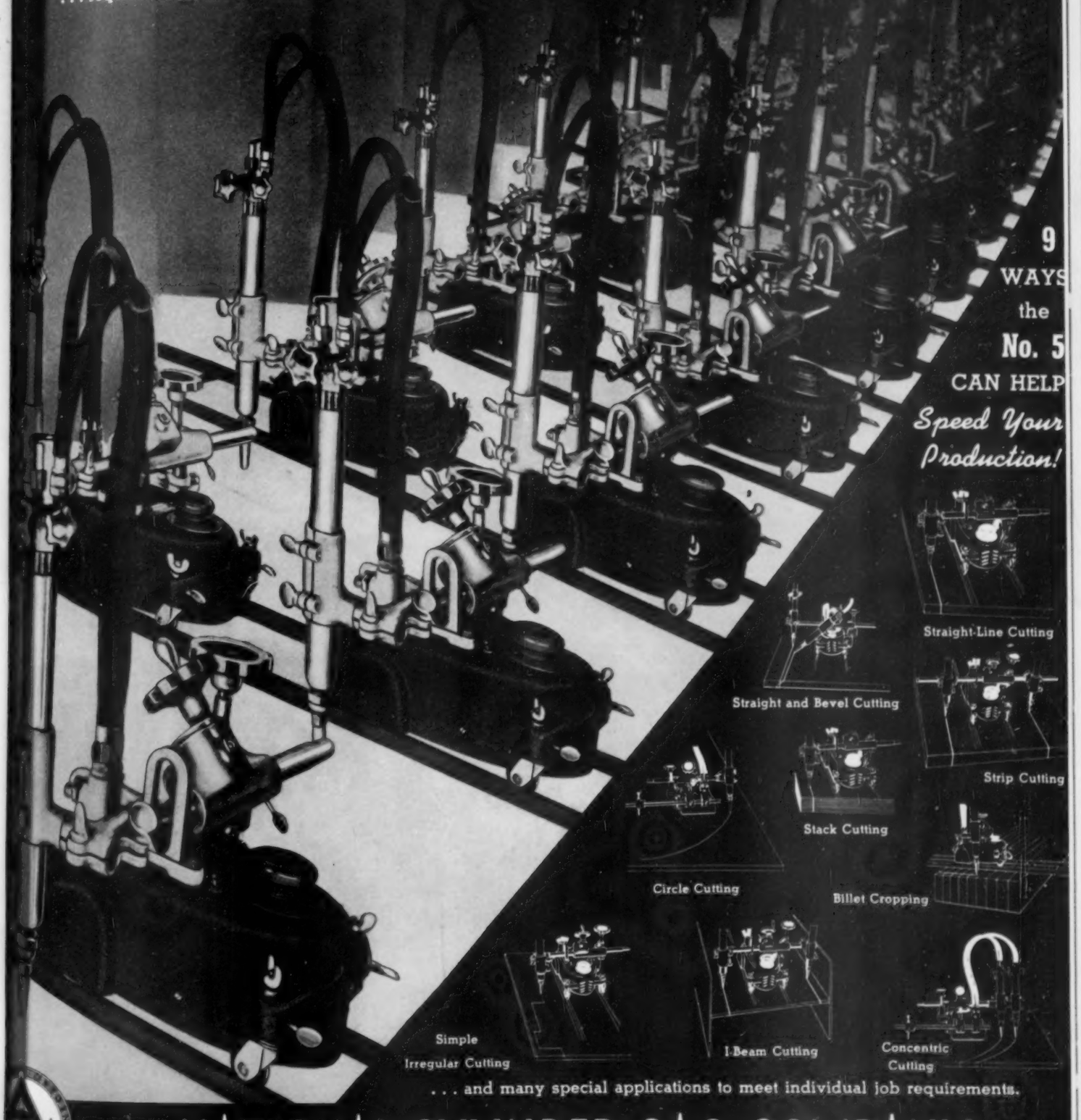

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Ott, Albert C. (C), Excel Curtain Co., Inc., 1120 N. Main St., Elkhart, Ind.
Stephenson, G. W. (C), Southwestern Oil & Ref. Co., Box 1147, Corpus Christi, Tex.

SECTION ACTIVITIES

BOSTON

This section joined with the Boston Chapter of the American Society of Metals on March 6th to hear Mr. G. O. Hoglund, Research Engineer on Welding, and Mr. Charles Braglio, Research Engineer on Fabrication, Aluminum Company of America, discuss "Recent Developments in the Fabricating, Welding and Heat Treating of Aluminum Sheets, Bars and Shapes." Two reels of motion pictures, "Fabrication of Aluminum" and "Unfinished Rainbows," were shown.

At the dinner preceding the meeting Mr. N. D. Valentine, Special Agent of the Federal Bureau of Investigation, was the Coffee Speaker.

Dr. R. S. Williams, Head of Department of Metallurgy, Massachusetts Institute of Technology, acted as Technical Chairman of the joint meeting.

CANAL ZONE

The Canal Zone Section announces the election of the following officers for the fiscal year:

Chairman, Paul J. Cannell; *Vice-Chairman*, Clifford B. Jones; *Secretary*, Robert E. Hollick; *Treasurer*, James G. Murray.

CHICAGO

The February 20th meeting of the Chicago Section featured a very interesting program on the subject of "Non-Destructive Weld Testing Methods—A Symposium on X-Ray, Gamma Ray, and Magnaflux." Mr. E. W. Page, Manager of Industrial Sales, General Electric X-Ray Corp., spoke on X-ray, Mr. Philip D. Johnson, Technical Adviser, Radium Chemical Co., dealt with Gamma Rays and Mr. Roy O. Schiebel, Service Engineer, Magnaflux Corp., handled the Magnaflux phase of the subject.

All of the speakers were well qualified and presented a complete story on the principles, methods of application and interpretation of results. It was brought out that such tests locate hidden defects which can then be corrected, thus serving as a means of routine inspection. In addition, interpretation of results provides the basis for learning techniques that will eliminate imperfections in future fabrications, thereby pointing the way to improved quality in the finished product.

The attendance at this meeting was the largest of any affair held by the Chicago Section this season. In the audience were men from industry, as well as naval and ordnance inspectors, many of whom are employing the test methods described. As a result, a lively and instructive discussion followed the speakers' appearance.

At the March 20th meeting, two speakers of national renown presented talks on "resistance welding." Mr. S. M. Humphrey, Chief Electrical Engineer, and Mr. J. H. Cooper, Welding Engineer, both from the Taylor-Winfield Corp., dealt with "Stored Energy Welding" and "Resistance Welding on Defense Items." Both of the subjects are of major importance at this time and created a lot of interest.

Mr. M. S. Hendricks has resigned as Secretary of the Chicago Section and Mr. T. B. Jefferson, editor of *The Welding Engineer*, has been appointed to take his place.

The programs for the coming meetings are as follows:

April 17th—"Shape Cutting and Flame Hardening." Speaker to be announced.

May 15th—"Certified Weldments" by R. W. Sternke of the Lakeside Bridge and Iron Co., Milwaukee, Wis. The speaker's company is engaged in the fabrication of much important equipment where controlled welding is employed and he has an interesting story to tell.

CLEVELAND

Two nationally known welding authorities addressed the March 11th meeting of the Cleveland section of the AMERICAN WELDING SOCIETY at Cleveland Engineering Society Hall.

La Motte Grover, Structural Welding Engineer for the Air Reduction Sales Co., New York, spoke on, "Welded Steel Structures," and discussed development of welded design for building and bridge construction, also structural welding problems in shipbuilding. Mr. Grover is a charter member of the AMERICAN WELDING SOCIETY Bridge Committee, chairman of its subcommittee on design and active on many technical research committees of the SOCIETY and other organizations.

E. W. P. Smith, consulting Engineer with The Lincoln Electric Co., Cleveland, spoke on, "Polarized Light Models," explaining and illustrating, by use of slides, the study of stress distribution in welded joints by means of polarized light. The models of welded joints, made of a suitable material, such as celluloid, were placed in a beam of polarized light and any effects resulting from stresses imposed on the models were shown by changes in color bands in the polarized beam. Mr. Smith has been with Lincoln for twenty-three years, has lectured throughout the country and is a regular contributor of welding articles to technical magazines. He regularly conducts courses in welding engineering and is co-author of "Procedure Handbook of Arc Welding Design and Practice," published by his company.

The "coffee talk," following the banquet, was "Guns and Tanks" by Lieut. M. K. Henderson of the Steel Division of the Cleveland Ordnance District. Lieut. Henderson, formerly with the American Magnesium Co., explained the operation of the Ordnance Department and the speeding up of production of war equipment.

Members have been reminded of the Spring Conference scheduled for May.

COLUMBUS

Col. G. F. Jenks, President of the AMERICAN WELDING SOCIETY is scheduled to speak at the May 8th meeting of the Columbus Section, which will be held at Battelle Memorial Institute.

DETROIT

On March 2nd the Detroit Section of the SOCIETY held a joint meeting with the Detroit Section of the Society of Automotive Engineers. This was a dinner meeting at which there were 250. After dinner some 350 attended the meeting. Mr. Paul Merriman of Glenn L. Martin Co. spoke on "How to Increase Aircraft Output by Welding;" and Lieut. Harold Mulbar, Deputy Chief of Detectives, Michigan State Police, spoke on the subject of the Fifth Column in Michigan. This was one of the most interesting meetings for both Sections.

The meeting on May 1st will be "Past Chairmen's Night, Ladies' Night, House of Magic." Following the successful experience of last year, the Section will honor those chairmen who have been responsible for the continuity of its activities. There will be no speeches as such, but there will be entertainment in the form of "House of Magic" and dancing which will prove of interest not only to members, but also to their wives and sweethearts.

LOS ANGELES

April 16—High Velocity Tensile Testing of Welds; Aviation Welding of Large Jigs.

May 21—Resistance Welding.

June 18—Welding Dirt Moving Equipment; Railroad Welding; Aviation Inspection.

MARYLAND

The following is the program for the remainder of the season for the Maryland Section.

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April 17th—Subject: "Electric Resistance Welding." Speaker: J. R. Merriman, Glenn L. Martin Co.

May 15th—Annual Banquet and demonstrations.

MILWAUKEE

The regular monthly meeting of the Milwaukee Section was held on February 27th. An after-dinner talk was given by Richard Jordan, General Manager, Better Business Bureau of Milwaukee, who spoke on "Current Rackets." The welding address was given by Mr. C. E. Swift, Manager of Welding Division, Ampco Metals, Inc., whose address was on "Welding with Copper Alloys." The subject included a review of the welding of all copper alloys by all welding processes and the use of copper alloy welding rods on other metals.

An invitation was extended to the Milwaukee Section by the Milwaukee Chapter of the American Society for Metals, to attend their meeting on March 17th, which was devoted to a Welding Symposium, with the following subjects and speakers: "Gas Welding," Gustave Johnson, Air Reduction Sales Co.; "Welding of Cast Iron," H. O. Quartz, Allis-Chalmers Mfg. Co.; "Atomic Hydrogen Welding," Jerome B. Welch, Cutler-Hammer, Inc.; "Arch Welding," Louis J. Larson, Welding Consultant; "Structural Welding and Welding of General Machinery Weldments," E. C. Brekelbaum, Harnischfeger Corp.

NEW YORK

The New York Section of the AMERICAN WELDING SOCIETY held a joint technical meeting with the Metropolitan Section of the American Society of Civil Engineers at the Engineering Societies Building on March 10, 1942. Chairman for the evening was Mr. F. H. Frankland, Director of Engineering, American Institute of Steel Construction.

The first speaker of the evening was Mr. John F. Willis, Engineer of Bridge Design, Connecticut Highway Department, Hartford, Conn., who spoke on the subject, "Development of Welding of Connecticut Highway Bridges." Mr. Willis, who has been responsible for the design of many of the bridge structures that are such an essential part of the Connecticut Motorway System, told of the reasons leading up to the use of welding, the growth of the process in bridge construction and the difficulties which have been encountered in the final acceptance of welding as a sound practice.

Following Mr. Willis' talk, Dr. Miller McClintock, Traffic Consultant and one of the nation's leading authorities on traffic control, spoke on the subject, "Roads North." Dr. McClintock reviewed the network of highway systems leading north from the New York metropolitan area and illustrated his talk with numerous lantern slides.

During the half-hour period preceding the technical meeting, the regular "Welding and Cutting Question Box" Session was conducted by Mr. R. E. Bedworth, Westinghouse Electric and Manufacturing Company, New York.

Mr. James Partington, Manager of the Engineering Department of the American Locomotive Company, will be the technical speaker at the April 14th meeting, to be held in Room 502, 33 West 39th St., New York. Mr. Partington's subject will be "Welding Applied to Locomotives."

Through the courtesy of the General Electric Company and the American Locomotive Company, there will be a presentation by the General Electric Company of "Railroadin'." This is a 30-min., full color and sound motion picture, full of action. It is the story of America's railroads.

NORTHERN NEW JERSEY

The March meeting of this Section was held on the 17th. Mr. T. N. Armstrong of the International Nickel Company spoke on "Welding of Nickel Alloys." Mr. Armstrong explained why and how the procedures and techniques are varied, and told how to get best welding results with these materials. Dr. A. B. Kinzel of the Union Carbide and Carbon Research Laboratories spoke on "Welding of Chrome Alloys." Dr. Kinzel discussed the metallurgical and physical properties of the more commonly used alloys. A movie, "Nickel High Lights," was presented through the courtesy of the International Nickel Company.

The program for the April meeting, to be held on the 21st, is as follows: "Welding in the Pressure Vessel Industry," J. T. Phillips, Supt., Boiler Shop, Foster Wheeler Corp. Movie: "Manufacture of Large Diameter Pressure Vessels."

NORTHWEST

Mr. LaMotte Grover, Structural Welding Engineer, Air Reduction Sales Co., spoke on "Welded Steel Structures" at the March 19th meeting of this Section. Mr. Grover's talk was illustrated with a number of slides showing welding in shipbuilding.

An annual meeting will be held by the Northwest Section on May 14th.

OKLAHOMA CITY

The Oklahoma City Section of the AMERICAN WELDING SOCIETY met for dinner at the Biltmore Hotel on March 5th. This was one of the most interesting meetings of the entire year, with all the speakers being provided by local industrial concerns.

Mr. Bob Perry, in the person of Archo, mystified the diners with sleight-of-hand and other magical manipulations.

During the dinner, C. C. Willis, Chairman of the Local Section, asked for the Executive Committee recommendations concerning the following proposals: First, in addition to the membership offered in the prize contest between the University of Oklahoma and the Oklahoma A. & M. College, an additional membership prize will be offered to any student enrolled in a private or a defense welder training course in the Oklahoma City District, said enrollee to submit a paper concerning some phase of welding, which shall be judged superior to any of the others submitted. The second proposal, which was also approved, consisted of a recommendation that the knowledge and experience of the Local Section be made available through the Committee of the Local Section to any manufacturer, company or individual concerned with defense work, and who might have need of information or advice concerning welding or heat-treating problems.

Francis Sprehe of Midwest Steel, Oklahoma City, gave a short talk concerning a roof truss framework constructed by his firm for a local theatre building. The trusses were fabricated entirely by welding. A considerable saving in cost, plus more satisfactory design and appearance from an architectural standpoint, was secured.

Mr. Ray Jacoby of Black Sivalls and Bryson gave an interesting illustrated talk concerning the industrial applications of photography, especially as concerned with welds and welded products.

Mr. Jacoby was followed by Mr. K. B. Banks of Black, Sivalls and Bryson. Mr. Banks's talk, which was illustrated also, was concerned with the history and design of welded pressure vessels. Eighteen members attended the dinner, and thirty-nine were present for the meeting.

The program for May and June is as follows:

May 7th—Arthur N. Kugler, Mechanical Engineer, Applied Engineering Department, Air Reduction Sales Company, New York City, N. Y. Subject: "Designs of Jigs and Fixtures for Welding." Dinner Meeting, Biltmore Hotel, 6:30 P.M.

June 4th—Annual Meeting, installation of officers and Dutch Lunch.

PEORIA

The May meeting of this Section will be held on the 6th at 7:30 P.M. at the Central Illinois Light Company Auditorium, 310 South Jefferson St., Peoria. Mr. C. J. Holslag of Electric Arc, Inc., will speak on "Crater Cracks and Fish Eyes, Their Cause and Cure." A moving picture, "Smelting and Refining of Lead," will be shown.

PHILADELPHIA

The regular monthly meeting of the Philadelphia Section was held on February 16th. Mr. L. H. Scheifele, Engineer of Tests, The Reading Company and C. R. R. of N. J., spoke on "The Welding of Railway Equipment." Mr. Scheifele gave an account of the extensive use of welding in the Reading Company shops.

At the March 16th meeting Mr. A. N. Kugler, Engineer, Air Reduction Sales Co., spoke on "Gas Welding in National Defense." Mr. Kugler's paper covered a review of oxyacetylene procedures which may be employed under current Government specifications.

The April meeting will be held on the 20th at the Engineers' Club, 1317 Spruce St. Mr. A. Amerikian, Design Engineer Bureau of Yards and Docks, will speak on "Welded Buildings."

The May meeting will be held on the 18th also at the Engineers' Club. The subject will be "The Welding of High Pressure Piping."

PITTSBURGH

Over one hundred members and guests turned out to hear Mr. Frederick H. Dill, Welding Engineer, Ambridge Division, Pittsburgh, Pa., discuss "Structural Welding Under Current Codes and Specifications" in the Mellon Institute, Wednesday night, February 18th. A sudden change in the weather bringing near blizzard conditions and making roads almost impassable tended to keep away an expected record attendance.

However, those who attended were more than repaid for their presence in having presented to them one of the most complete discussions of this subject ever presented.

Mr. Dill covered the problem thoroughly, bringing out the particular items of interest in the various specifications, making comparisons and suggestions as to probable changes.

Following the presentation many questions were asked by those present and it was voted a most interesting meeting.

PUGET SOUND

Announcement of the Annual Tri-State Conference on April 24th was made.

Mr. E. J. Gorde of Taylor-Winfield Corporation spoke on "Resistance Welding as Applied to Defense Industries" at the March 19th meeting held at the 40 et 8 Club, Seattle. Mr. Gorde showed an interesting motion picture film in connection with his talk. Mr. J. A. Luetke of Air Reduction Company spoke on "Flame Cutting."

ROCHESTER

Mr. Paul W. James, Lincoln Electric Co., addressed the March 5th meeting on "Properties, Characteristics and Specifications of Filler Rod."

ST. LOUIS

The regular monthly meeting of the St. Louis Section was held on March 13th. Mr. LaMotte Grover, Structural Welding Engineer, spoke on "Welded Steel Structures."

The May meeting will be held on the 8th. Mr. C. J. Holslag of Electric Arc, Inc., will speak on "Crater Cracks and Fish Eyes, Their Cause and Cure."

SAN FRANCISCO

The February meeting of this Section was held on the 27th. Through the courtesy of the Bethlehem Steel Company, a sound picture on "The Manufacture of Wire Products" was shown. Mr. Miles S. Farwell, Consulting Engineer for the Bethlehem Steel Co., showed the picture and answered questions.

At the March 20th meeting, through the courtesy of The Linde Air Products Co., Mr. C. S. Smith showed a motion picture, entitled "The Unionmelt Welding Process."

SOUTH TEXAS

Mr. E. J. Brady of Alloy Rods Company, York, Pa., addressed the membership of the South Texas Section at the Ben Milam Hotel, Houston, on February 17th. The subject discussed was "Arc Welding Stainless Steels," and the application was to commercial and defense problems. Mr. Brady explained the metallurgical changes that occur in welding stainless materials such as 18-8, and pointed out the advantages and disadvantages of using stabilizing elements in steels of this type when they are to be welded.

A lively discussion with questions and answers followed the speaker's address, and many points of local interest in alloy welding were clarified.

WASHINGTON

The fifth regular meeting of the Washington Welding Society was held February 24th, at 8:00 P.M. in the PEPCO auditorium. The speaker, Mr. Zimmerman of The Linde Air Products Co., presented a paper on flame cutting and flame treating. Mr. Zimmerman showed many interesting slides on the equipment and the procedures used in flame cutting and treating.

One of the high points in his talk was "flame strengthening." By this process parts of a member can be strengthened and weak points in design eliminated. This process is a special application of flame hardening.

Mr. R. B. Swope, Sr., president of the Washington society, expressed the group's appreciation to Mr. Zimmerman, and the meeting was adjourned.

WESTERN NEW YORK

One of the most interesting and instructive meetings of this section was held February 20th at the Markeen Hotel.

After the dinner meeting a short discussion was held relative to the course in Welding Theory being started by Cornell University in conjunction with the University of Buffalo under the Defense Education Program.

The speaker of the evening, Dr. W. G. Theisinger, Director of Welding Research, Lukens Steel Company, gave an illustrated talk on "The World's Largest Plate Mill," and the discussion period following was greatly enriched by Dr. Theisinger's many years of research experience on welding problems.

YORK-CENTRAL PA.

An Annual Banquet was held by this Section on March 18th. Dr. A. B. Kinzel, Chief Metallurgist, Union Carbide & Carbon Res. Labs., was the guest speaker. Dr. Kinzel spoke on "Welding of Alloy Steels."

CALENDAR OF EVENTS

Society and Section Meetings

(For further details see Section Activities)

TENTH LECTURE NEW YORK SECTION LECTURE COURSE—April 7, 1942.

NEW YORK SECTION—April 14, 1942.

LOS ANGELES SECTION—April 16, 1942.

CHICAGO SECTION—April 17, 1942.

MARYLAND SECTION—April 17, 1942.

PHILADELPHIA SECTION—April 20, 1942.

NORTHERN NEW JERSEY—April 21, 1942.

PITTSBURGH SECTION, TRI-STATE CONFERENCE—April 24, 1942.

DETROIT SECTION—May 1, 1942.

PEORIA SECTION—May 6, 1942.

OKLAHOMA CITY SECTION—May 7, 1942.

COLUMBUS SECTION—May 8, 1942.

ST. LOUIS SECTION—May 8, 1942.

NORTHWEST SECTION—May 14, 1942.

CHICAGO SECTION—May 15, 1942.

MARYLAND SECTION—May 15, 1942.

LOS ANGELES SECTION—May 21, 1942.

OKLAHOMA CITY SECTION—June 4, 1942.

Meetings of Other Societies

FIRST WESTERN HEMISPHERE FOUNDRY CONGRESS FOUNDRY AND ALLIED INDUSTRIES SHOW, 46th Annual Convention, April 20–24, 1942.

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